The Face inversion Effect and Perceptual Learning: Features and Configurations.

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I certify that all material in this thesis that is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Signature.................................

ABSTRACT

This thesis explores the causes of the face inversion effect, which is a substantial decrement in performance in recognising facial stimuli when they are presented upside down (Yin,1969). I will provide results from both behavioural and electrophysiological (EEG) experiments to aid in the analysis of this effect. Over the course of six chapters I summarise my work during the four years of my PhD, and propose an explanation of the face inversion effect that is based on the general mechanisms for learning that we also share with other animals. In Chapter 1 I describe and discuss some of the main theories of face inversion. Chapter 2 used behavioural and EEG techniques to test one of the most popular explanations of the face inversion effect proposed by Diamond and Carey (1986). They proposed that it is the disruption of the expertise needed to exploit configural information that leads to the inversion effect. The experiments reported in Chapter 2 were published as in the Proceedings of the *34th annual conference of the Cognitive Science Society*. In Chapter 3 I explore other potential causes of the inversion effect confirming that not only configural information is involved, but also *single feature orientation information* plays an important part in the inversion effect. All the experiments included in Chapter 3 are part of a paper accepted for publication in the *Quarterly Journal of Experimental Psychology*. Chapter 4 of this thesis went on to attempt to answer the question of whether configural information is really necessary to obtain an inversion effect. All the experiments presented in Chapter 4 are part of a manuscript in preparation for submission to the *Quarterly Journal of Experimental Psychology*. Chapter 5 includes some of the most innovative experiments from my PhD work. In particular it offers some behavioural and electrophysiological evidence that shows that it is possible to apply an associative approach to face inversion. Chapter 5 is a key component of this thesis because on the one hand it explains the face inversion effect using general mechanisms of perceptual learning (MKM model). On the other hand it also shows that there seems to be something extra needed to explain face recognition entirely. All the experiments included in Chapter 5 were reported in a paper submitted to the *Journal of Experimental Psychology; Animal Behaviour Processes*. Finally in Chapter 6 I summarise the implications that this work will have for explanations of the face inversion effect and some of the general processes involved in face perception.

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Chapter 1: General Introduction

1.1 Specific and general mechanisms in face perception

Face recognition is perhaps one of the best cognitive skills that individuals have. We do generally recognise familiar faces with very little effort, despite large variations in lighting, viewpoint and expression. Discussion of the nature of face perception has been mainly divided between two interpretations: One of which makes the assertion that a large body of research supports the notion of specialised mechanisms used to process facial stimuli (Farah Tanaka and Drain, 1995; Rhodes and Tremewan, 1994; Valentine, 1988; Yin, 1969): Whilst the other points out that in the last thirty years there have been many studies showing that face recognition is actually based on general mechanisms that can also operate for other non-facial stimuli as well (Diamond & Carey, 1986; Tanaka and Farah,1991). One the most robust phenomena, and central to this debate, is the face-inversion effect (FIE), which is the disproportionate drop in recognition performance for upside down (inverted) faces relative to upright faces (Yin,1969). At its discovery, the FIE was described as a clear consequence of the specialised mechanisms used in face processing. This explained why the impairment in recognising upside down faces was significantly larger than that for other objects (Yin,1969). However, this interpretation has been challenged by the finding that an FIE as large as the one for faces can be also obtained with images of dogs (Diamond and Carey,1986). I will now review some of the key studies in face inversion that have supported both the special and the general mechanism accounts. I will begin with the original discovery of the FIE and the first interpretation of this effect.

1.2 The face-specific mechanism account of the FIE.

1.2.1 *Yin's (1969) findings.*

Recognition of objects that are usually seen in one orientation is sometimes strongly impaired when the same objects are turned upside down, revealing how intrinsically difficult it is to identify them. This was found to be particularly the case for faces, a phenomenon known as the face inversion effect (FIE) (Arnhein, 1954; Attneave, 1967; Hochberg &Galper, 1967, Dallet, Wilcox, & D'Andrea, 1968). Thus, the fact that recognition of human faces is more impaired by inversion than is recognition for other stimuli has underlined how faces are in some sense, special. In early evidence for the FIE, Yin (1969) presented participants with upright or inverted pictures of faces, airplanes, houses, and other stimuli. Following the study phase participants were then tested with stimuli in the same orientation in a recognition task. The results showed that when the stimuli were studied and tested in an upright orientation, faces were better recognised than other sets of stimuli. However, when the same stimuli were presented and tested in an inverted orientation, recognition for faces was poorer relative to the recognition levels for the other classes of stimuli. Yin (1969, Experiment 3) replicated this result in an experiment using line drawings of facial stimuli and period costumes, thus controlling for the effect of subtle shadow information in an inverted face as a potential explanation for the large effect of inversion. In the latter experiment, faces were not the easiest stimuli to be recognised when presented in an upright orientation. Therefore, the large FIE could also not be attributed to the overall difficulty in discriminating within that stimulus category. Later experiments by other researchers have confirmed Yin's results, e.g. Valentine and Bruce (1986) found a FIE for face recognition compared to recognition of houses in experiments where upright and inverted stimuli were presented in the same list during the test phase. All the previous studies in the literature had used separate test blocks. In summary, the FIE seems to be a solid and general phenomenon that cannot be explained simply as an artefact of experimental procedure, stimulus material, or task demands. Yin interpreted his results in terms of a face-specific process.

1.2.2 *Stimulus familiarity and specificity for faces (Scapinello and Yarmey, 1970)*

Scapinello and Yarmey (1970) investigated differences in stimulus familiarity using sets of pictorial stimuli presented in either upright or inverted orientations. More specifically, their study was based on comparing recognition of human faces, canine faces and architectural stimuli under the same orientation and familiarity conditions. Thus, each participant in their study was presented with a set of stimuli in an upright orientation and half of this set of stimuli were presented just once (low familiarity) and the other half were presented for 7 additional trials (high familiarity). The results from the recognition task showed that pictorial stimuli in the high familiarity experimental condition were significantly better recognised than the ones in the low familiarity condition. However, familiarity failed to affect the special effect that inversion has on recognition of human faces. All types of stimuli were harder to recognise on inversion, but the effect of inversion was significantly greater for human faces than for other stimuli. In a follow-up study Yarmey (1971) explored further the effect of inversion on recognition of familiar faces. In that study, familiarity of human faces was manipulated by using pictures of well known public people, who were easily recognisable by name as stimuli. The study was designed to investigate if verbal encoding (names)would reduce the difficulty in recognising inverted familiar faces. The same three types of stimuli previously employed by Scapinello and Yarmey (1970) were used again in this study, thus sets of human faces, facial photographs of dogs and photographs of buildings. However this time a set of faces of familiar personalities was also used, for example, Frank Sinatra or Richard Nixon. Half of the subjects were given an old /new recognition task just after the study phase. The other half were tested in the same manner, but with 20 minutes delay after the study phase. The results showed that all materials were more difficult to recognise if inverted. In particular, both familiar and unfamiliar faces and canine faces showed a significant inversion effect, but there was no significant effect of inversion for buildings. These results, with the exception of canine faces, agreed with Scapinello and Yarmey's (1970) findings. In addition, although dog faces were difficult to recognise on inversion, the magnitude of the inversion effect for human faces was twice that for dog faces. Taken together, the results from Scapinello and Yarmey (1970) and Yarmey (1971) demonstrated that the effect ofinversion for human faces seems to be relatively independent of familiarity. They proposed that human faces are coded in a specific manner, thus perception of people cannot be equated to perception for other objects, since human faces are likely to elicit special psychological properties. We can speculate that the inversion effect obtained for dogs was related to subjects anthropomorphizing dogs but not buildings. In addition to these cognitive processes, the authors suggested that sensory variables such as brightness, texture and size must be used in the encoding of faces. Finally, these results showed that verbal encoding of faces (names) facilitated the recognition performance for upright faces, however it did not affect performance when faces were presented under inversion. These results supported Yin’s (1969) thesis that the disproportionate decrement in recognising human faces is based on a face-specific factor. Additional support for this thesis comes from studies on brain-damaged patients.

1.2.3.1 *Neuropsychological brain injuries and Face Recognition*

Perhaps the strongest support for the specificity account of face recognition comes from neuropsychological studies on patients with brain damage. The key idea behind these studies is that they provide a unique opportunity to compare the face-specific and the general mechanism accounts. This is because if certain brain injuries specifically affect faces, but not object recognition, this would be strong evidence that face recognition is based on some face-specific mechanism. Conversely, if the injury also affected object recognition then the opposite conclusion could be drawn. A syndrome in which patients are unable to recognise familiar faces has become known as ‘prosopagnosia’ (Bodamer, 1947). However, other studies have shown that the deficit found in prosopagnosia is often related to visual recognition rather than something specific to faces, thus, they showed other deficits that these patients have. For example, an inability to distinguish one chair from another, supporting the idea of a more general deficit (Bay,1953). Following these early studies on brain injuries and face recognition, many other authors have designed and administered face recognition studies to a larger sample of the patient population. This has resulted in robust evidence for the claim that patients with right posterior cerebral damage find it very difficult to recognise faces, doing significantly worse than patients with brain injuries on the opposite hemisphere or control subjects (DeRenzi and Spinnler,1966; Benton and Van Allen, 1968; Milner,1968). DeRenzi and Spinnler (1966) have directly compared recognition for faces and for objects in these patients. The results from their study showed that right posterior injuries, but not other ones, disrupted performance on different recognition tests in which they used faces, abstract figures, and chairs, though recognition for chairs was only mildly affected. However, faces and abstract figures were more impaired, hence abstract figures seem to have been treated more like faces than chairs. The authors concluded that the impairment in recognising faces was based on a more general difficulty in making subtle discriminations. However, other authors have criticised these results, proposing that the differences in the three recognition tests could have just reflected the difficulty of the task alone (Yin,1970).

1.2.3.2 *Right posterior brain damage and Face Inversion (Yin,1970).*

Yin (1970) compared recognition performance for upright and inverted facial stimuli in normal and brain injured individuals. The aim was to test the proposition that patients with right hemisphere brain injuries were specifically affected in recognising faces. Thus he proposed that right posterior injuries, which presumably lead to decreased recognition of faces in their usual orientation, should also show less effect on inverted faces; and if this was found for faces it should not hold for the recognition of other familiar stimuli normally seen in one orientation. Thus different categories of patients were selected to take part in the experiment. Some patients had bilateral brain damage; some others had unilateral (right or left) frontal injuries, and finally patients with unilateral brain injuries anywhere else but the frontal-area.

Thus the experimental procedure consisted of each participant being tested in an old/new recognition task similar that used in Yin’s (1969) study. Subjects first were tested with a study phase in which a set of stimuli (faces or house) were presented one at a time in their usual upright orientation. Following in the test phase a set of upright stimuli were presented in pairs and the subject had to indicate the one stimulus he had seen before during the study phase. At the end of this recognition task the subject was tested again with the same experimental procedure but this time the sets of stimuli were shown in inverted orientation. All subjects were tested in recognizing the four stimulus’ conditions, i.e. images of faces and houses in both upright and inverted orientations. The results showed that patients with certain right-hemisphere injuries were impaired relative to normal individuals and left hemisphere patients only at recognising upright faces not at recognising inverted faces. Thus, Yin (1970) proposed that this double dissociation demonstrates that the inversion deficit is specific to face recognition. He also noted that the test involving houses was not affected by these manipulations as much as that with faces. Thus Yin concluded that these patients were injured to their specialised face processor. Finally, Yin also proposed that the face recognition deficit consequent on inversion seems to have something to do with some perceptual difference between upright and inverted faces. He speculated that the upright faces might have some characteristics that the inverted faces lack.

1.2.3 *Brain specific mechanism for face inversion in monkeys (Bruce, 1982)*

Thus far we can see how face inversion has been used to dissociate face recognition processes from general mechanisms for object recognition. And the evidence from neuropsychological patients with injuries in the right hemisphere is consistent with there being specific mechanisms for processing faces. In addition, other studies have shown that when stimuli are confined (by means of brief visual presentation in the appropriate visual hemifield) to only one cerebral hemisphere of healthy right-handed adults, only the right hemisphere shows the face inversion effect (Leehey, Carey and Diamond, 1978). In a subsequent study, Bruce (1982) investigated if face inversion would affect also monkeys' ability to recognise faces. In this study Bruce (1982) used a cohort of six Macaque monkeys and presented them with a learning discrimination task by rewarding them with food to the positive stimulus. The stimuli used were a set of colour slides of monkey faces presented in upright and inverted orientations. The results showed that there was no reliable effect of face inversion on the monkeys. The author interpreted this result as being very surprising because Macaque monkeys are very similar to humans on the basis of many psychological and psychophysical measures e.g. categorisation, colour, discrimination, sensitivity, acuity. Furthermore, as is the case for humans, it is also the case for monkeys that the face plays a major role in identification and communication within many primate societies. The fact that monkeys did not show any effect of inversion suggested that they perhaps lack a specific mechanism for face recognition that only humans seem to have and which is confined to the right hemisphere of the brain.

1.3. The general mechanisms account of face and object inversion effects.

1.3.1. *Word and face inversion effect; an effect of mental rotation (Rock, 1973;1974).*

Back in 1973, Rock found one class of stimuli that seemed to be more affected by inversion than human faces. Specifically, handwritten words (e.g. ‘quiescent’, ‘untimely’) were recognised at 86% when presented in an upright orientation and at 9% when inverted. For human faces the corresponding scores were 71% and 12%. It could be possible that completely different processes affect performance in recognising inverted faces and inverted handwritten words. However, Rock (1973, 1974) proposed a general explanation for both sets of stimuli. He suggested two main factors that may be involved in the perception of disoriented objects: an assignment of direction factor and a retinal factor. When an object is seen at a moderate distance from the viewer, it does not appear small in spite of the fact that its retinal image is much smaller than when the object is presented near to the viewer. Rock explained this effect by saying that the information supplied by the retinal image is corrected by allowing for the distance of the object from the viewer. Thus, when people are presented with upright figures but with their head tilted, before they make any corrections, they begin with the information given by an image of the figure in a particular retinal orientation. The first step is for the perceptual system to process the retinal image by assigning top, bottom and sides. The example that Rock reported is the upright square seen by a viewer with his head tilted which elicits a diamond like retinal image. To the viewer the square would seem like a diamond unless the correction was applied. Head orientation is automatically taken into account to correct the perception. This correction is made very quickly with little effort. Thus, to recognise a figure the viewer has to visualise or imagine it in terms of its real top, bottom and sides rather than in terms of its retinal top, bottom and sides. When a more complex figure such as a face is inverted, these corrective mechanisms may be overtaxed. This is because the face contains a number of features each of which needs to be properly perceived in order to recognise the whole face (Leon & Harmon,1973). Thus, while the viewer's processes try to correct one feature inside an inverted face, the rest of the features remain uncorrected (Rock 1973, 1974). This mechanism proposed by Rock is somewhat similar to that studied by Shepard and Metzler (1971) in a task where participants were asked to rotate images of three-dimensional objects at different orientations mentally in order to compare them.

The two accounts just described are representative of one of the key debates in face inversion effect research. Yin 's (1969) account proposes a specific mechanism for the recognition of faces, whereas Rock (1973,1974) postulated a general mechanism that is overstretched by the complexity of faces. Rock suggested that the difficulty in recognising inverted faces is mostly a perceptual problem of correcting the orientation of the inverted stimulus. Thus, this perceptual explanation would require individuals to try to rotate the face and store it the right way up. In conclusion, Yin's theory claims the existence of specific brain mechanisms with the sole function of processing faces, whilst Rock proposes a more general perceptual phenomenon to explain the inversion effect.

1.3.2. *Orientation-specific configurational representation of upright faces in child development (Diamond and Carey, 1977)*

Studies of face inversion in infants have shown an early benefit for the processing of upright faces compared to inverted faces. Experiments on 16-18 week old infants indicated that they are able to discriminate an upright face from the same face turned upside down (Fagan, 1972; McGurk,1970; Watson, 1966). Furthermore, Fagan (1972) found that infants of 20-27 weeks were able to discriminate between two different upright faces, although this discrimination failed when stimuli were presented under inversion. Thus, from these studies it was clear that there was a developmental advantage for discriminating upright faces rather than inverted ones. However, a few years later (1979) Fagan reported results from an experiment which showed how abstract patterns were discriminated by 22-week-old infants better in one orientation than in another. Therefore, the author concluded that infant's recognition of faces should not be considered a specific or unique process applicable only to faces.

Diamond and Carey (1977) suggested that Yin's results with healthy and brain damaged patients show that faces might be represented mentally in two different ways, one of which is also shared with other stimuli. The first of these two ways is based on the features of the face stimulus in isolation, so for example a mole, or bushy eyebrows could be used. These features can be recognised equally well in inverted or upright orientations. Human faces however also have distinctive spatial relationships among their features, representation of which might be exploited more easily when the facial stimuli are presented in their usual orientation. Perhaps Yin's patients had lost the ability to use these configurational characteristics of the faces presented to them, since no difference was found between normal controls and patients related to inverted presentation of the faces. Diamond and Carey (1977) investigated whether these two kinds of representation of human faces may show different developmental courses. In the first experiment in their study a sample of children divided by three groups around the ages, 6, 8, and 10, were presented with sets of images of facial stimuli and houses in upright and inverted orientations. After the study phase, a recognition task was given comprising pairs of images containing a stimulus that had been seen in the study phase and a new stimulus of the same type. The already seen stimuli were presented in the same orientation as in the study phase. The results showed that 6 and 8 year old children did not show a significantly greater inversion effect for faces compared to that for houses. However, for 10 year old children the effect of inversion for faces was significantly bigger than the one for houses. Additionally, while the recognition performance for upright faces improved sharply between 6 and 10 years old, that for inverted faces stayed constant. Finally 6 and 8 year old subjects did as well on inverted faces as did adults, the only difference in performance between 6 and 8 year old children and adults was on upright faces. Thus, the authors concluded that the substantial effect of face inversion that seems to emerge by age 10, is caused by the development of an efficient way to represent faces in their usual orientation, perhaps by using configural information. A quite different result was found for house recognition. Performance in recognising upright houses remained constant, but that for inverted house stimuli was at chance at 6 years old, improving significantly by age 10. The authors suggested that the diminishing effect of inversion in houses might reflect an improvement in encoding the piecemeal features of a relatively unfamiliar stimulus like a house from an inverted exemplar. In the same study the two authors ran a second experiment in which they provided clear evidence that 6 and 8 year olds used isolated features in face recognition performance whereas 10 years old children did not. They created four types of recognition problems by manipulating facial expression and paraphernalia like hairstyle, or glasses, or clothes. The children were presented with an inspection image and then this was covered while a pair of images were shown. The subject was asked which one was the same person. The subject was informed that the facial expression or the hair or the eyeglasses of the person might have changed. The results showed that 6 and 8 year olds were highly affected by paraphernalia cue change. However, this effect decreased by age 10. In addition, their results showed that children at 6 years old were able to solve the problem when the facial faces used were familiar to them. The authors suggested that older children (age 10) based their judgements on the properties of the faces that led to correct identification. Finally, the authors concluded that these two experiments taken together implied that these properties are the configurational information of the faces, aspects that can be better encoded from faces presented in an upright orientation. The fact that young children can solve the paraphernalia problem when the faces are familiar to them suggests that familiar faces are represented as configurations by young children, and the ability to form configurational representations of unfamiliar faces is attained by age 10. What could be the cause for this developmental change? The authors proposed that perhaps experience with real faces may be required. And also perhaps the ability of configurally represent faces may depend on maturational changes in the right cerebral hemisphere.

1.3.2 Configural information and dog inversion effect *(Diamond and Carey, 1986).*

In line with Diamond and Carey's (1977) proposition, a few other studies had shown how important configurational relations might be for face recognition. For example, Harmon (1973) provided evidence that configural information alone is sufficient to support face recognition. In his study he showed that images of faces were highly recognisable even when the main facial features were degraded by a blurring manipulation. Haig (1984) showed in his study that subjects were sensitive to small manipulations in the spatial relationships between the features within the face. In addition, Sergent (1984) has provided clear evidence on how inversion affects configural information for schematic faces in a matching task. In her study, a set of eight photo-fit faces was created, each of which was differentiated from the others on at least one of three dimensions: jaw, eyes, contour, and configural information (internal spacing) of the eyes and nose relative to the mouth. The hypothesis was that if configural information was processed, then a regression analysis should yield interactions between the component dimensions. Such interactions were obtained for upright stimuli but not for inverted ones for both accuracy and reaction times. Additional results from the same study showed that variations in the configural information did not affect latencies for inverted faces. Finally latencies on upright and inverted faces did not correlate significantly when the pairs differed on configural information. These results support the idea that relational information is used to match upright faces, but it is less available on inversion.

In 1986 Diamond and Carey conducted one of the highest impact studies in the face inversion literature and more generally on face recognition. In Experiment 1 of their study they used two sets of stimuli: faces, and landscapes, which were selected because they share several characteristics with faces. In particular, like faces, landscapes have isolable features that bear spatial relations to each other. Another similarity is that faces and landscapes are both very familiar classes of stimuli. The procedure used across the whole study was the same as the one used by Yin (1969). Thus participants were first presented with a study phase in which were asked try to memorise a set of stimuli. Following this there was a recognition task in which a pair of images was presented and participants had to indicate whether they had seen any those images before or not. There were two series of stimuli presented in the recognition task, one with inverted images and one with upright images. The presentation of the two sets of stimuli was counterbalanced across the participant groups. The results from Diamond and Carey's (1986) Experiment 1 showed that in the upright condition subjects performed on the two materials (faces and landscapes) comparably well. In the inverted condition performance was more disrupted for faces than for landscapes. The authors suggested two possible explanations for the fact that the inversion effect was larger for faces than that for landscapes: - It could be that landscapes possess more isolated features than faces, and this could have helped subjects to perform better in the inverted condition; - A second possible reason is the fact that human faces share all the same basic configuration, thus for example the eyes always above the nose, the nose above the mouth and so on. However all landscape images do not share the same basic configuration. Thus, based on the different configuration, the landscapes can be still discriminated quite easily even when inverted, whereas for a pair of faces for example it would harder to discriminate them given that they share same basic configuration. Diamond and Carey (1986) proposed that this common basic configuration shared across the main features within a face can be called *first-order relational information.* However, for faces, as for other classes of stimuli that share a configuration, the first-order relational information is constrained because it represents the average configural distance between the main features. Thus, what distinguishes the exemplars of such a category of stimuli are the deviations in the spatial relations between the elements that define the shared configuration. They referred to these as *second-order relational* *information*. Following this logic, the authors proposed that perhaps by taking a class of stimuli which share an overall configuration, as is the case with faces, they might be able to obtain an inversion effect as large as the one normally obtained for faces. Already in 1970 Scapinello and Yarmey had constructed a set of dog images and found a smaller inversion effect for those images compared to that for images of faces. However, the big caveat for that study was that the participants were students who did not have much familiarity with dogs, or at least not the equivalent of a life-time seeing human faces. In Experiment 2 of the same study Diamond and Carey (1986) presented dog experts and novices with images of dogs and human faces in both upright and inverted orientations. The results showed that the experts were more affected by stimulus inversion when encoding dogs than were novices, although this effect was not significant. The problem with the set of stimuli chosen was that the three breeds of dog images belonged to different dog groups. Thus, if experts were specialised in more than one breed, probably those breeds were in the same group. The breeds used in Experiment 2 were not well matched with the expertise of the participants.

Thus, in Experiment 3, this time the materials were confined to the breeds on which the subjects were indeed expert. The results showed that for faces all participants showed the usual large inversion effect, thus 88% of responses were correct for upright faces, and 65% for inverted ones. For experts there was also a similar effect of inversion for images of dogs, with upright dogs being recognised up to 81% mean accuracy, and 59% for inverted images of dogs. This time the inversion effect for experts was significantly greater that that for novices when presented with images of dogs. The authors concluded that the inversion effect for dogs can be as strong as that for faces, suggesting that there may be other factors that affect recognition on inversion which are not specific to faces. They proposed that this factor is expertise, defined it as the ability to exploit second-order relational properties, and hypothesized that it is lost on inversion. And, once the key information needed to discriminate between members of a class is lost, performance decreases significantly.

1.3.3. *Manipulations of the Configural Information and the FIE (Leder, Huber and Bruce, 2001).*

Searcy and Bartlett (1996) and later Leder and Bruce (1998) have provided compelling evidence on the effect of disrupting configural information by inversion. In one of their experiments, Searcy and Bartlett (1996) made faces grotesque by either changing local elements, such as blackening teeth, blurring the pupils; or by changing the facial configuration. When shown in an inverted orientation, faces that were distorted through configural changes seemed to be more similar to the normal version, while the “locally distorted face” still looked grotesque. Thus, configural changes did not survive the inversion process as well as local ones. In another experiment, Leder and Bruce (1998) distorted faces so as to be more distinctive, either changing local features by giving them darker lips, bushier eye brows, etc. or by changing configural information to give a shorter mouth to nose spatial relation, etc. Distinctiveness impressions caused by distorted configural information disappeared when faces were presented in an inverted orientation relative to both upright faces and faces distorted in their local aspects. Finally, Leder, Huber and Bruce (Experiment1, 2001) investigated whether orientation would affect sensitivity in detecting differences in the spatial relations between the eyes. Subjects were presented with sets of faces which had their interocular distance manipulated. Four different versions of each facial stimulus with four different interocular distances were created. The subject’s task was to indicate which of two stimuli presented in every trial possessed the largest interocular distance. The results showed that turning a face upside down leads to a decrease in sensitivity to differences in interlocular distance, consistent with Diamond and Carey’s (1986) theory.

1.3.4 Configural information and The Thatcher Illusion (Thompson, 1980).

“I dropped in to my local Conservative Association office. Margaret Thatcher had, the previous May, won the general election, defeating Jim Callaghan's Labour government which had been undone by the `winter of discontent'. The smug officer I encountered in the party office was all too willing to let me have a couple of left-over posters from that election campaign. Once home I spread the two posters side by side on the floor and set about Margaret Thatcher with a razor blade. I cut out the eyes and mouth and inverted them, little knowing that I

had just carried out the first `Thatcherisation'. The effect twas extremely pleasing: one of my posters looked wonderfully grotesque. I reasoned that if I showed my class both the undoctored image and the `Thatcherised' image at a distance they would look identical, but, as one approached, the true awfulness of one would become apparent. All I needed to do now was to stick the pieces of the Thatcherised image together. I left the room and went to collect some adhesive tape. When I returned I approached the side-by-side images where they lay on the floor. By chance they were arranged so they were upside down as I approached. And it was then I realised that the image that a couple of minutes previously had thrilled me with its awfulness, now looked happy and smiling" (Thompson,2009, p. 921-922).

This sensitivity of configural distortions to inversion is also often suggested as the basis (at least in part) of the "Thatcher illusion" (Thompson, 1980). The "Thatcher" illusion is an orientation sensitive face illusion. In the original version, pictures of the then British PM, Margaret Thatcher, were manipulated by rotating the eyes and mouth by 180 degrees. The result of this is that the face would look odd when shown in an upright orientation but not when shown inverted. This manipulation of the eyes and mouth is also called *Thatcherisation*. Here, the illusion seems to depend on the inversion of mouth and eyes within the face being hard to detect when the whole face is inverted. The explanation typically offered is that inversion reduces the use of configural information in the face, and promotes a more componential analysis of the features present. In isolation, the mouth and eyes do not look odd, and so cause no great reaction in the viewer. When the face is shown in its normal orientation, however, we revert to configural processing, and this makes the distortions present in the mouth and eyes stand out, resulting in a strong reaction to the face on the part of most percipients.

1.3.4.1*The Thatcher Illusion in other-race faces (Murray, Rhodes and Schuchinsky, 2003).*

Several studies have documented that faces from an unfamiliar racial group are more difficult to recognise than faces from one's own race (Bothwell, Brigham, & Malpass, 1989; Chiroro & Valentine, 1995). The common explanation given is that it is a result of a reduced ability to process configural information in faces for which people have less expertise. For example, Rhodes Brake and Taylor

(1989) examined the differences in recognition performance on own-race and other-race faces using the inversion paradigm. The idea behind the experiment was intuitive, if a reduced ability to process configural information in other-race faces produces poorer other-race recognition, then inversion should have a less disruptive effect on other-race faces compared to own-race faces. This is what Rhodes et al., (1989) found in their studies, confirming the significant role that configural information has in face recognition. This other-race effect based on configural information finds more support from Fallshore and Schooler (1995)'s study. The authors found that verbally describing an already seen face leads to worse recognition of the same face in a subsequent forced-choice recognition task. They suggested that this verbal overshadowing effect is a result of over focusing attention on the featural information at the expense of configural information when a verbal description of the face is given. Thus, the authors also hypothesised that if inversion disrupts use of configural information in the own-race stimuli, then the verbalisation manipulation would not have any impact for inverted own-race stimuli. The results from their studies provide evidence for their prediction. These studies are consistent with the view that is the perceptual processing of configural information that is disrupted by inversion and is the basis for our expertise with faces.

Murray et al., (2003) investigated the Thatcher illusion and its link with configural processing using the other-race effect. They predicted that the bizarre impression of a Thatcherised face would disappear, or at least be reduced, if Thatcherisation is applied to other-race faces. Thus, the lower expertise for the configural information of other-race faces would reduce the strong impact that Thatcherisation normally has on the viewer.They also hypothesised that no effect of inversion should be present for other-race Thatcherised faces. Thus, the participants were tested in a bizarreness judgement task, in which they rated the bizarreness of a set of faces on a scale from 1 to 7 where 1 indicated the most normal looking face and 7 the most odd one. All the subjects were Caucasians who rated the Caucasian (own-race) and Asian (other-race) facial stimuli in separate sessions. In each session the faces were shown in three different conditions: unaltered, Thatcherised and component distorted. Results from the Thatcherised stimuli showed a significantly reduced inversion effect for other-race Thatcherised faces. Their analysis of this result was that since the perception of bizarreness in the

Thatcherised faces was created by manipulating configural information, it followed that other-race faces would be perceived as less bizarre than own-race faces, and be less affected by inversion. These results provide evidence for the powerful effect that configural information has on the processing of upright faces relative to inverted. These results also found additional support from developmental studies of the Thatcher illusion.

1.3.4.2. *The Thatcher illusion in child development (Donnelly and Hadwin 2003).*

In 2003 Donnelly and Hadwin investigated the effect of the Thatcher illusion in children. They aimed to provide additional evidence for the development of configural processing. Several earlier studies had shown the that the development of configural processing is such that it only emerged significantly in children at around 10 years age (Diamond and Carey,1977; Friere and Lee, 2001). In Experiment 1 Donnelly and Hadwin (2003) presented participants with a detection task in which subjects had to choose which of the two otherwise identical faces looked the most “unusual” in both upright and inverted orientations. The children were divided into groups by age thus, 6 - 7 and 8- 10 years old. There was also a group of adults participating in the study. In Experiment 1 the authors found that young children perceived the Thatcher illusion, suggesting that they process configural information in facial stimuli. Thus, Experiment 1 indicated the presence of configural processing in young children, contradicting the finding that configural processing is weaker in children compared to adults (Carey and Diamond, 1994). However, the authors suggested that the possible developmental effects may have been obscured since the interaction between orientation and age was at ceiling for the upright stimuli. In Experiment 2 the authors used the same sets of faces; this time, however, all the images were saved as monochrome images creating stimuli similar to Mooney faces. The aim was to establish whether these stimuli would allow a better exploration of the development of configural processing. The results from Experiment 2 showed that when using these monochrome faces children as young as 6 years old did not perceive the Thatcher illusion. The results were consistent with configural processing being present at 8 years old. However the experience of the illusion increased with age until adulthood. This suggested that the configural processing found in 6-year old children was not as developed as that found for 10 year old children and adults. These results support the idea that configural processing increases with expertise due to experience with faces. Thus, these results all provide evidence for the powerful effect that relational information has on the processing of upright faces relative to inverted faces.

1.3.5.1 *Perceptual learning theories and pattern inversion effect (McLaren, 1997).*

But there is still a question as to what precisely is the difficulty caused by any disruption of configural information consequent on inversion. The suggestion from some theories of perceptual learning (e.g. McLaren, 1997) is that expertise for faces enhances the use of configural information by effectively reducing the salience of first order relational information (which is also configural), leaving second order relational information relatively salient which aids discrimination. Thus, once configural information in upright faces has been disrupted, the benefits conferred by our expertise with those faces would tend to decrease, making them less easy to discriminate from one another. This explanation for the effect of expertise in face processing has some empirical support. The key finding is that it has been shown that experience with exemplars of a category that can be represented by a prototype (and have second order relational structure as a result of their variation about that prototype) leads to an increased ability to discriminate between members of that category (McLaren, Leevers and Mackintosh, 1994). This improvement is lost when the stimuli are presented in an inverted orientation (McLaren, 1997).

McLaren, Kaye and Mackintosh, (1989) provided an associative mechanism that can explain the effect of expertise on face recognition that was then further developed in McLaren and Mackintosh (2000). Expertise with a category represented by a prototype will tend to lead to the unique discriminating elements of exemplars constructed from that prototype becoming relatively more salient (more active) compared with the prototypical ones which are shared across exemplars. This model of associative learning makes predictions about the inversion effect that are consistent with McLaren's (1997) experiments. The first experiment demonstrated that the inversion effect is dependent both on the subject's familiarity with a category and on the category being defined by a prototype. Subjects were exposed to a set of chequerboards and were asked to categorise them into two different categories. This was followed by a discrimination task that included two pairs of chequerboards (one pair in an upright and the other pair in an inverted orientation) from a familiar category, plus two control pairs of chequerboards from a novel category (again one pair upright the other inverted). The results showed that familiarity with a category that was defined by a prototype gave subjects an enhanced ability to discriminate between exemplars of that category in an upright orientation. This benefit was lost when the stimuli were inverted. There was no effect of inversion for a familiar category that was not prototype-based. Finally, in a second experiment it was shown that the results also applied to recognition, in that experience with a prototype-defined category again resulted in a significant inversion effect on a same / different task. These results strongly suggest that it is familiarity with the second-order structure within a category that is the basis of the expertise that leads to improved recognition performance for exemplars of such a category. If either the requisite structure or the requisite familiarity with that structure are not present then the inversion effect is absent. I will return to these studies in a later chapter in this thesis (Chapter 5) when I investigate the role of perceptual learning in the FIE. I will also defer any discussion of other theories of perceptual learning (e.g. those based on non-associative comparison processes such as that of Eleanor Gibson, 1969) until the General Discussion. This is because, for present purposes, all the theories of perceptual learning of which I am aware can be interpreted so as to generate the same prediction, that familiarity with a class of mono-oriented stimuli will lead to perceptual learning that aids differentiation between exemplars of that class when upright, a benefit that is lost on inversion. Thus, in general, theories of perceptual learning predict a face inversion effect based on expertise with facial stimuli.

1.3.5.2 *Second-order relational information and the inversion effect (Tanaka and Farah, 1991).*

In 1991, Tanaka and Farah directly investigated the role that second-order relational information may play in producing the FIE. In their study they trained subjects to identify dot patterns that either shared a common configuration, with each exemplar having been constructed from a prototype by means of small variations in dot position, or did not share a common configuration. Dot patterns were selected as stimuli because they can be discriminated only on the basis of spatial relations. Dot patterns that do not share a configuration can be discriminated based on their first order properties. According to Diamond and Carey's (1986) theory, the set of dot patterns that do share a configuration can be discriminated on the basis of second-order relations, because these patterns will have highly similar first-order relations. Hence, participants' discrimination between them will be based on the encoding of second-order relational properties. In the study phase the participants learned to identify the first-order and second-order patterns by female or male names. In the recognition task they were asked to identify the same dot patterns presented in either upright or inverted orientations. The hypothesis was that if second order relational information causes the inversion effect, a more severe performance decrement should have been obtained from dot patterns that share a configuration than from the ones that did not. In the two experiments the authors conducted, they found a moderate inversion effect that did not differ in magnitude between the two types of patterns. In Experiment 1, in the upright orientation 93% of the second-order relations patterns were identified correctly against 87% on inversion. Very similarly, 94% of the first-order patterns were identified correctly in an upright orientation compared with 88% on inversion. The authors ran a second experiment in which they modified the second-order relation patterns by increasing the degree to which these stimuli shared a configuration. However the results, as in the Experiment 1, did not show a greater effect of inversion for the second-order than for the first-order relational patterns. Their conclusion was that greater reliance on second-order relational information (assumed to occur in the prototype defined case) does not directly result in a greater sensitivity to inversion. The implication of this finding is that both configural information (first and second relations) seem to be subject to the inversion effect. Thus the FIE does not selectively influence second-order relational properties.

1.3.6.1*The "Holistic" representation of human faces(Tanaka and Sengo,1997).*

Some additional support for Tanaka and Farah's position comes from Tanaka and Sengco's (1997) study. The authors hypothesized that if both featural and configural information are combined into a *holistic* representation, then changes in configural information should affect the recognition of the individual facial features. In Experiment 1 subjects were presented with a set of faces in which the eyes were moved either wide apart or close together. After the study phase, subjects recognised parts of the faces either presented in isolation, within a new configuration, or in the old face configuration. The only difference between the new and old configuration conditions was the eye spacing. According to the authors' holistic theory, the participants should have recognised the facial features better in the old configuration, where the second-order information was preserved, compared to the new configuration where that information was changed. Additionally, the holistic theory predicted that changes in the configuration would have also affected subject's performance in recognising the other features whose spatial relations were not directly manipulated. The results from their first experiment are consistent with this hypothesis: after training with upright faces, the participants recognised facial features better in the unaltered facial context than in the context where the second-order information had been disrupted (by changing the distance between the eyes). Subjects recognised isolated features on 65% of trials. The same features presented in a new configuration were recognised on 72% of trials. Finally when the features were shown within the old configuration the correct recognition performance increased to 77%. Reliable differences were found between the three conditions, suggesting the holistic hypothesis. Finally, comparing the performance on the unaltered nose and mouth in the two configural conditions showed that when the second-order relations were changed for the eyes alone, this also affected recognition for the unaltered features. In a second experiment, the authors further investigated the relation between featural and configural information by comparing recognition of features from normal faces with that from a set of inverted faces. The results showed that manipulations that disrupted configural information did not affect recognition for facial features when the faces were presented upside down. Thus, their conclusion was that manipulating configural information, in particular second order relational information, only affects the recognition of facial features in the case of upright faces.

More evidence for this view comes from Rhodes, Brake, and Atkinson (1993). In their study they used several types of manipulation to investigate the effect of inversion on detecting changes in feature as well as configural information.

There were three main manipulations used: 1) A feature change based on the presence or absence of glasses or a moustache; 2) Another feature manipulation, this time swapping one of the internal face components (mouth or eyes) with those from another face; 3) A second-order relational information manipulation achieved by varying the internal spacing of the eyes and the mouth (shift eyes apart and mouth up, or eyes together and mouth down). The results from the old/new recognition task used in this study showed that there was no inversion effect for manipulation 1, but a strong inversion effect was found for both manipulations 2 and 3. The authors noted that manipulations of second-order relational information (altering the internal spacing of the eyes and mouth) were more difficult to detect when faces were inverted. However, when the eyes or mouth were actually replaced with those from another face (manipulation 2), this was more disruptive to recognition performance under inversion. They concluded that either the feature changes also affected configural information or the assumption that feature processing is not affected by inversion is incorrect (Schwaninger, Carbon and Leder, 2003).

In summary, there is quite strong evidence suggesting that configural information is important for face processing, is implicated in the FIE and may become more important as a function of experience (expertise). On the other hand, there is also some evidence that configural information does not necessarily play a significant role in the FIE, and at least some of the evidence supporting the claim that it does play a role may well be susceptible to alternative explanations.

1.4.1 Electrophysiological (ERPs) and Functional Brain Imaging (fMRI) investigations of the FIE.

In the last few decades several electrophysiological (EEG) and functional brain imaging (fMRI) studies have investigated the FIE, and, more generally, face perception. From the studies reported so far in this chapter it is clear that behaviourally the investigation of the FIE had focused on two main issues, the specificity vs. expertise accounts and the configural vs. featural information issue. With respect to the first issue, the EEG literature has generated a component named the N170 that originally was believed to be specific to face stimuli (Bentin, Allison, Puce, Perez and McCarthy, 1996). However, the specificity of the N170 in response to faces was challenged by the finding that the same N170 component could be elicited by sets of “Greebles” (Rossion, Gauthier, Goffaux, Tarr and Crommelinck, 2002) once subjects were familiarised with that class of stimuli. The same debate has been the subject of experiments employing functional brain imaging (fMRI) techniques. Some fMRI studies have focused on comparisons between particular object categories, leading to the view that in human inferotemporal cortex there are regions specific to the recognition of facial stimuli. In particular, results from these studies suggested that part of the middle fusiform gyrus is dedicated to recognising faces (Haxby et al., 1994; Kanwisher et al., 1997). However Gauthier et al., (1997) has shown that a region of the fusiform and inferotemporal cortex similar to that activated for faces was found to be engaged in processing non-face objects as well.

1.4.2.1*The N170 and face perception (Bentin et al., 1996)*

The N170 is the first posterior negative deflection following the visual presentation of a facial image, peaking at occipito-temporal regions with maximum amplitude occurring between 150-200 ms (Bentin et al., 1996). Bentin et al. (1996) investigated the N170’s properties in a target detection task study in which the participants were presented with five different categories of visual stimuli (normal faces, scrambled faces, cars, scrambled cars and butterflies) and asked to count the number of a specified target category presented (e.g butterflies). The negative ERP peaking at 172 ms (N170) was largest for normal faces. The N170 amplitude in both left and right hemispheres was significantly larger for faces compared to all other categories of stimuli, with no differences between those other categories. In the same study, Bentin et al. (1996) tried to determine whether the N170 was specific to faces or could be elicited by other familiar body parts. This time, using cars as the target, the participants were presented with images of human faces, animal faces, and human hands. Once again human faces evoked a larger N170 compared to the other stimuli, whereas there was no significant variation in the latency of the peak. These results suggest a specificity of the N170 to human faces that reflects the activity of cells in detecting human faces rather than information about body parts or other categories of stimuli (Bentin et al., 1996). We can now ask how inversion might affect the N170. If the N170 was specific to detecting facial features prior to their recognition, inversion of the faces should affect this component of the

ERP. However if the N170 reflects activity in a neural circuit regulated to identify facial features prior to the recognition of the face, it may not be sensitive to face inversion.

1.4.2.2 The FIE and the N170 (Bentin et al., 1996)

Bentin et al. (1996), in a similar experiment to the one just described, investigated the effect of inversion on the N170 ERP component. The participants were presented with images of faces and cars shown either upright or in an inverted orientation. The N170 elicited by inverted faces in this study had similar amplitude to the one elicited by upright faces; however, it was significantly delayed, by about 10 ms, relative to the N170 elicited by faces in their normal upright orientation. Cars and inverted cars elicited equivalent ERPs but without much by way of a N170. The similar N170 amplitude elicited by upright faces and inverted faces supported the notion that the N170 was not linked to recognition of a particular face, but was more likely to be associated with the neural mechanisms involved in the analysis of visual stimuli allowing the categorisation of a stimulus as a face (Valentine & Bruce, 1988).

1.4.3.1*Expertise effect on the N170 modulations (Rossion et al., 2002)*

Given that the only stimuli that result in a substantial inversion effect are the ones for which the subjects have the necessary expertise (Diamond & Carey, 1986), this suggests that the face inversion effect may not be due to the fact that facial stimuli are subject to special processing because they are facial in nature, but instead that there are other factors, such as expertise, which are causal in producing the effect. This view receives support from studies such as that of Rossion, Gauthier, Goffaux, Tarr and Crommelinck (2002) who have shown that it is possible to obtain an electrophysiological inversion effect for an experimental non-face stimulus class called ‘Greebles’ once participants are trained in recognising them. Rossion et al. (2002) trained participants with a three-phase experiment in which there was first a baseline phase where ERPs were recorded from responses to face and Greeble presentations in both upright and inverted orientations. Following this, there was a training phase using only upright Greebles. Finally, during the last phase of the experiment ERPs were measured using new faces and new Greebles presented in both upright and inverted orientations. ERPs prior to the training phase revealed the inversion effect to be larger for faces than for Greebles. Following training with upright Greebles, the N170 latencies for the upright faces and Greebles were similar. The ERPs for inverted faces remained roughly constant before and after the training phase with Greebles, but ERPs to Greebles showed a significant training effect, in that there was an increased delay and increased amplitude for inverted Greebles as compared with Greebles presented in an upright orientation. In conclusion, although the inversion effect for faces was larger in both experimental sessions, the inversion effect for Greebles increased with increasing expertise with that category of stimuli. These results suggest that ERP inversion effects are tied to expertise with a category rather than the category of faces per se. However it is important to note that the main criticism about Greebles is that they are still facelike because mono-orientated and share a quite similar configuration as that for faces.

1.4.3.2 *Expertise effect on the N170 (Tanaka and Curran, 2001)*

Other ERP experiments have shown a strong link between expertise and the N170 component in recognising non-face objects. Tanaka and Curran (2001) investigated the neural basis of object expertise while recording the brain activity of experts in categorising images of common dogs and birds. Results showed that the magnitude of the N170 was larger when the participants categorised objects in the domain in which they were expert than when they categorised objects in the domain in which they were novices. Furthermore, the magnitude of the elicited N170 was not influenced by any expectation primed by the category. For example, dog experts displayed an N170 of equal magnitude in response to an image of a German shepherd regardless of whether the presented image was preceded by the category labels “bird” or “animal”. The N170 elicited in response to objects for which participants had expertise was similar in latency and scalp distribution to the N170 elicited in many studies for faces. De Haan, Pascalis & Johnson (2002) investigated the inversion effect and the link to expertise using human and monkey faces, as the latter have a similar configuration of features to human faces. These two categories of stimuli were presented to participants in both upright and inverted orientations. Results revealed the N170 as being different in amplitude for upright human faces compared to all other sets of stimuli. In particular, the N170 amplitude evoked by upright faces was smaller than for other stimuli, and the amplitudes for monkey faces both upright and inverted, and inverted human faces did not differ significantly from one another. Thus, inversion increased the amplitude and latency for human faces but not for monkey faces. The same experiment conducted on 6-month-old infants produced a component with similar morphology to the N170. However, this infant component differed from the N170, both because it peaked 100 ms later and it was not affected by inversion. Thus, for adults the orientation of faces played a role in determining the N170 (Eimer, 2000), but for infants the influence of orientation appeared only at later processing stages. This absence of an inversion effect in the infant ERP's is consistent with the idea that adults develop expertise for face processing, including both species and orientation, as a consequence of experience with that stimulus category (de Haan et al., 2002).

In conclusion, the results from the studies considered in this section when taken together support the view that experience with stimuli may have a role in driving the specialization of processes subserving face recognition. They have also moved us away from the original conceptualisation of the N170 as being specific to faces and relatively unaffected by their inversion, to a position where the amplitude is less for upright faces than for inverted faces, the peak occurs somewhat earlier, and similar results can be obtained for at least some categories of stimuli if they are made sufficiently familiar. This is the view of the N170 that I will take forward when we report the results of the EEG study run in chapter 5 using sets of prototype-defined familiar chequerboards.

1.4.4.1*Brain activations to the FIE (Kanwisher et al., 1998)*

Perhaps the strongest evidence in support of the specificity account of face recognition came from Moscovitch et al.,'s (1997) study on a neurological patient, CK. The authors showed that although CK was severely impaired on a wide range of visual tasks, for example, word and object recognition, CK was absolutely normal at the recognition of faces presented in an upright orientation. Furthermore, CK showed a face inversion disadvantage that was about six times greater than that obtained in normal individuals. The authors explained these results by arguing that the face specific mechanism was still unaltered in CK, and was unable to process inverted faces. In support of this finding several imaging studies (Kanwisher et al., 1997; McCarthy et al., 1997) have found a focal region in the fusiform gyrus, also named the fusiform face area or FFA, that is highly activated in response to faces compared to other stimulus types. Thus, in 1998 Kanwisher et al., investigated whether the FFA area responded to faces alone or perhaps to a defined visual feature that tended to be present in faces, and whether it was true that inverted faces cannot elicit activation in a face specific mechanism as proposed by Moscovitch et al.,(1997).The authors used two sets of faces: greyscale faces which disrupt the ability to recognise the face, but without affecting the ability to detect a face; and Mooney faces in which, by contrast, inversion disrupts face detection (George et al., 1997). Thus, the FIE for greyscale faces should reflect face recognition processes, whereas that for Mooney faces should be sensitive to face detection processes. In Experiment 1 the results from a 1-back matching task (which required more attention to inverted than upright faces) showed as strong activity in the FFA for inverted as that for upright greyscale faces. Thus inverted greyscale faces were clearly able to activate the FFA to a substantial extent. This result argued against the claim the Moscovitch et al., (1997) that inverted faces cannot activate face specific mechanisms. Experiment 2 of the same study, using two-tone Mooney faces, showed a greater FFA activation to upright than inverted stimuli. The FFA response was much lower for inverted Mooney faces than for upright, and this effect was found to be consistent across subjects and tasks. Thus, the authors interpreted the results by suggesting that the lower response to inverted Mooney faces than to upright Mooney faces demonstrates that the FFA activation is not to be explained in terms of the presence of any specific visual features, but the FFA response is correlated with the perception of a face as a face. Finally, the large response to inverted greyscale faces demonstrated that the hypothesis that inverted faces are unable to engage face specific mechanisms is not correct.

1.4.4.2 *Greeble experts activate the FFA (Gauthier et al., 1999).*

Gauthier et al., (1999) explored the possibility that the FFA may be the result of individual expertise in seeing faces. Thus, in their study the subjects were trained with sets of novel objects named Greebles as mentioned before in this chapter. The subjects were trained at categorising these stimuli at an individual level and at a more general ‘family’ level, and a change in performance was considered to be diagnostic of expertise. The subjects were first fMRI scanned in an initial session before any exposure to the Greebles, and then following this at three different stages during training and twice after they reached the criterion for categorising Greebles. To investigate the nature of the expert processing for this type of stimulus the authors compared tasks with upright and inverted faces and Greebles. Thus, the within-class stimuli were matched in every perceptual aspect, but expertise should have been specific to the familiar upright orientation. In each fMRI session, subjects were presented with a sequential matching task in four conditions, with unfamiliar faces and Greebles in the upright and inverted orientation. In the first two scanning sessions more upright specific activation in the FFA was found for faces than for Greebles. But, by the end of the training sessions the preferential activation for upright faces over Greebles in the FFA was reduced and no longer significant. The FFA activation for upright Greebles minus inverted (FIE) increased significantly across training whereas the same activation for upright minus inverted faces (FIE) did not increase but actually decreased, although not significantly. This last result confirmed that the significant activation increase for Greebles was not due to a practice effect, which should have been common to the facial stimuli too, but actually it reflected the effect of developing expertise for Greebles. These results showed how the FIE can be obtained for faces in the FFA, and that a similar inversion effect can also be recorded for novel objects like Greebles after sufficient training. Finally, these results also suggest that the activation of the FFA can increase with expertise for novel objects.

In sum, the results of the main studies using functional brain imaging have provided evidence bearing on the debate as to whether the FFA, is or is not a face specific module. In particular there are two contrasting types of evidence. First, that the FFA is activated more strongly by faces than any other type of non-face objects (Haxby et al., 1994; Kanwisher et al., 1997). Second that under some conditions non-face objects can engage the same FFA area (Gauthier et al., 1999).

1.5 Introduction to the experiments.

In this Chapter I have summarised some of the main studies conducted in the face recognition area of research and, more specifically, on the inversion effect. One of the key debates in face recognition is whether faces are "special" requiring special processes for their perceptual analysis, or if our ability to recognise faces is just a result of our life experience in perceiving them. The face inversion effect has been used by many authors to address this issue in cognitive psychology. However, in terms of the inversion effect itself there is another debate that focuses on the actual causes of the drop in performance in recognising normal faces when they are turned upside down. In particular, many authors have proposed that an inability to make use of configural information when a face is inverted is the cause of this effect, whereas others have suggested that feature-based information might be more important. Thus, in this thesis I am reporting a number of experiments I have conducted in which I tried to clarify some of the issues related to both these two debates. My aim was to investigate the causes of the inversion effect by conducting experiments that analysed both the two main types of information believed to play a major role in the FIE, i.e. configural and featural information. Finally, I wanted to bring to bear some more evidence on the expertise account and consider an interpretation of the face inversion effect based on general mechanisms of perceptual learning.

Thus, In Chapter 2 I focus on a relatively small manipulation of the features within a face, namely Thatcherisation. The intention is to assess the extent to which isolated features and configural information determine the face inversion effect. I also introduce the use of ERP techniques in an attempt to provide neural correlates of my behavioural data. These experiments were the starting point for my research, but, as will become clear, they raised more questions than they answered, and cast some doubt on Diamond and Carey's explanation of the FIE without being able to definitively falsify it. On the positive side, Thatcherisation of the faces did affect the FIE in a reliable fashion, and this correlated with changes in the N170.

In Chapter 3 I removed all first and second order relational information from my face stimuli by scrambling them. If this information is critical to the FIE then it should disrupt, and possibly eliminate this effect. It did no such thing. I then applied a variant of the Thatcherisation manipulation used in Chapter 2 to demonstrate that, if a face's features were scrambled and half of the interior features were inverted, then the FIE disappeared. This final manipulated stimulus can thus act as a baseline for the other manipulations used in this thesis. These results strongly support the claim that the FIE, in part at least, is due to the orientation of the features in a face considered in isolation, i.e., it is not necessarily driven by configural information, be it first or second order.

In Chapter 4 I went on to answer the question raised in Chapter 3 as to whether first or second order information has any effect in determining the FIE. The results obtained in the four experiments reported in Chapter 4 show a clear effect of first-order relations on the FIE. Thus, I am able to show a strong inversion effect when single feature orientation and second order relational information are disrupted, by keeping first-order relations unaltered. I suggest that in order to activate a holistic process for perception of face-like stimuli, the first-order relations provide important information that can be used for this purpose and single feature information on its own may not be enough.

In Chapter 5 the focus shifts from consideration of whether feature or configural information is the basis of the FIE to whether the FIE is the product of expertise with a certain type of stimulus category, or whether it depends on perceptual mechanisms specialised for processing faces. In this chapter I extend the work of McLaren (1997) with chequerboards to my face recognition paradigm to see if I can replicate his effects, identify the components of any inversion effect relative to baseline, and provide ERP correlates for any inversion effect obtained with these stimuli. The last would allow me to tie these results in with the literature on faces and other "face-like" stimuli such as Greebles. This attempt is successful, and my conclusion is that there is strong evidence to suggest that the FIE has a component based on expertise.

Finally Chapter 6 summarises the main findings in this thesis and discusses them in the context of the background literature on face recognition and perceptual learning. I suggest possible implications these results would have for various theories of perceptual learning, and at the same time consider the implications that theories of perceptual learning have for the face inversion effect. In conclusion, I offer suggestions for further research that can continue the investigations I have started in this thesis.

Chapter 2: Face Inversion and Brain Potentials: The effect of Thatcherising faces.

2.1 Introduction to the experiments

Yin (1969) interpreted his inversion results in terms of a face-specific process. However, Diamond and Carey (1986) provided an alternative account of the FIE according to which the inversion effect is due to expertise for a prototype defined category rather than the product of face-specific processes. For the present purposes of his thesis, what was notable about this latter account was the emphasis placed on configural facial information as the basis for the FIE.

Diamond and Carey (1986) distinguished between three types of information that can be used in recognition: isolated features (e.g. the nose), first-order relational features (e.g. the nose in relation to the mouth) and second-order relational features (the variations in first-order relations relative to the prototype for that stimulus set). Thus, isolated or local features are the independent constituent elements of the perceptual object. First-order information consists of the spatial relations between the constituent elements of that object, and it is this information that defines a set of facial features as a face. Second-order information captures the variation in these spatial relationships with regard to the base prototype for objects of that type, and conveys information about the particular exemplar of that category. These two kinds of relational information are both types of configural information. Because all faces tend to have the same first-order relational information in common, the essential information by which faces differ from each other is second-order in nature on this analysis. Diamond and Carey suggested that large inversion effects can only be obtained if three conditions are met. First, the members of the class of stimuli must share a base configuration, the prototype. Second, it must be possible to individuate the members of the class by means of second-order information. Finally, individuals must have the expertise (in other words, the experience with the stimuli) to exploit such second-order information. They suggested that the perceptual elements that distinguish faces lie on a continuum from isolated/local to second-order relational, and that recognition of faces as a class differs from recognition of other types of stimuli in its reliance on second-order relational features exactly because people have the necessary expertise to use these features.

In this chapter I investigated the link between second-order relational structure and the face inversion effect suggested by Diamond and Carey (1986). The argument is that the improvement brought about by our expertise with faces is lost on inversion because this disrupts the ability to exploit second order relational information, leading to a strong inversion effect. In the behavioural part of this chapter (Experiment 1a and 1b), I aimed to demonstrate the typical strong inversion effect for normal face stimuli (for which we have expertise), and for comparison purposes ran a condition using what are known as Thatcherised face stimuli (see Fig.2.1 for examples). These latter stimuli serve as my experimental manipulation in the sense that they suffer from somewhat disrupted second order-relational information (even when upright) caused by the 180º rotation of the eyes and the mouth, which should reduce at least some of the effect of expertise in the upright orientation. Another useful characteristic of these stimuli is that they are still faces, and are well matched for complexity with the normal faces. I also investigated the electrophysiological responses to normal faces in comparison with the responses obtained to Thatcherised faces and predicted that the N170 would correlate with my behavioural results (Experiment 1c). That is, the N170 for upright normal faces was expected to be different from that obtained in my other conditions. I expected to observe larger and delayed N170 amplitudes for inverted normal faces, as well as for upright and inverted Thatcherised faces, by analogy with the results of de Haan et al. (2002). It is important at this point to acknowledge that I ran these experiments at an early stage of my research into these issues. The results obtained give a hint of what turned out to be a quite different explanation of the FIE from that proposed by Diamond and Carey (1986). The main concern with their theory is that by disrupting only the second-order relations the FIE is reduced, however, it does not disappear entirely and in some cases is even highly reliable (Experiment 1a). I shall return on this in the discussion section of this chapter.

2.2 EXPERIMENT 1a

2.2.1 Method

2.2.1.1 Materials

This study used 128 images in total, half female and half male. These were photographs of faces of former students at the University of Cambridge. The faces were standardised in grey scale format using Adobe Photoshop. A programme called Gimp 2.6 was used to manipulate the 128 stimuli. Any given face stimulus was prepared in four different versions i.e. normal upright, normal inverted, Thatcherised upright and Thatcherised inverted which were used in a counterbalanced fashion across participants so that each face was equally often used in each condition of the experiment. For the Thatcherised faces, each of the eyes and the mouth were flipped about the horizontal axis. Examples of the stimuli used are given in Figure 2.1. The experiment was run using Superlab Version 4.0.7b installed on an e-Mac computer.

Normal upright Thatcherised Upright Normal upright Thatcherised upright

Normal inverted Thatcherised inverted Normal inverted Thatcherised inverted

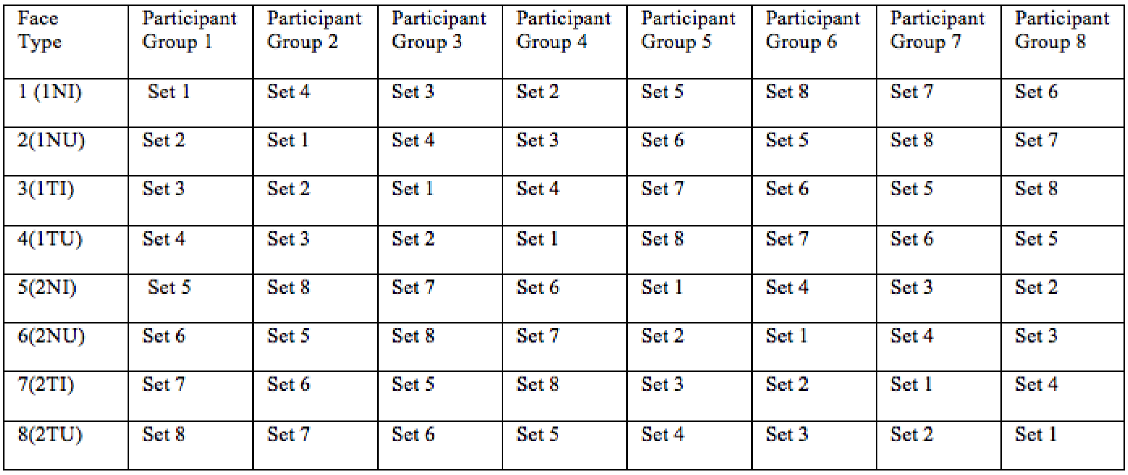
Figure.2.1. Examples of stimuli used in Experiment 1 showing the four different conditions with male and female faces. The dimensions of the stimuli were 5.63cm x 7.84cm. The stimuli were presented at a resolution of 1280 x 960 . Participants sat 1m away from the screen on which the images were presented.

2.2.1.2 Participants

The participants were 32 psychology undergraduates at the University of Exeter. The study was counterbalanced by splitting the participants into 8 groups. Each participant group was shown the same 128 faces, but each group saw each face in a different condition.

2.2.1.3 Procedure

The study consisted of a ‘study phase’ and an ‘old/new recognition phase’. After the instructions the procedure involved participants looking at 64 different faces (presented one at a time in random order) during the study phase. After further instructions, participants were then asked to look at 128 facial stimuli (including the 64 already seen previously) again presented in a random order. During this old/new recognition task participants indicated whether or not they had seen the face during the study phase. In the study phase each participant was shown 4 types of faces each with 16 photos (8 female, 8 male) for each face type (giving a total of 64 faces). These faces will be termed the “familiar” (designated as 1) faces for that participant. The face types were: Normal Inverted faces (1NI); Normal Upright faces (1NU); Thatcherised Inverted faces (1TI); and Thatcherised Upright faces (1TU). In the test phase another 64 novel faces (designated as 2) split into the same four face types were added to this set. Each facial stimulus had a unique identifying number, to make sure that individual faces never appeared in more than one face type at a time during the experiment. To simplify their use in the experiment, the facial stimuli available were divided into sets of 16 (8 male and 8 female) giving 8 sets of stimuli, and each participant group was shown a different combination of the 64 facial stimuli split over the 8 sets as shown in Table 2.1. Each participant saw the facial stimuli corresponding to their participant group in a different order. The first event that participants saw after the instructions consisted of a warning cue (a fixation cross in the centre of the screen) presented for 1 second, followed by a face presented for 3 seconds. Then the fixation cross was repeated and another face presented until all 64 facial stimuli had been seen. Once all 64 faces were shown, the programme moved to the next set of instructions, which explained to participants the nature of the old/new recognition task. Participants were told that they were about to see more faces presented one at a time in random order. They were asked to press the ‘.’ key if they recognised the face or to press ‘x’ if they did not. Each participant within each participant group was then shown (in random order) the 64 faces they had already seen intermixed with a further 64 unseen faces. These unseen faces were those from the sets of facial stimuli not used during the study phase.



Face Type	Participant Group 1	Participant Group 2	Participant Group 3	Participant Group 4	Participant Group 5	Participant Group 6	Participant Group 7	Participant Group 8
1 (1NI)	Set 1	Set 4	Set 3	Set 2	Set 5	Set 8	Set 7	Set 6
2(1NU)	Set 2	Set 1	Set 4	Set 3	Set 6	Set 5	Set 8	Set 7
3(1TI)	Set 3	Set 2	Set 1	Set 4	Set 7	Set 6	Set 5	Set 8
4(1TU)	Set 4	Set 3	Set 2	Set 1	Set 8	Set 7	Set 6	Set 5
5(2NI)	Set 5	Set 8	Set 7	Set 6	Set 1	Set 4	Set 3	Set 2
6(2NU)	Set 6	Set 5	Set 8	Set 7	Set 2	Set 1	Set 4	Set 3
7(2TI)	Set 7	Set 6	Set 5	Set 8	Set 3	Set 2	Set 1	Set 4
8(2TU)	Set 8	Set 7	Set 6	Set 5	Set 4	Set 3	Set 2	Set 1

Table.2.1. Combinations of facial stimuli presented to each participant group.

The sequence of events during the old/new recognition task was such that after the warning cue (1 second), a facial stimulus was shown for 4 seconds and participants had to respond during this period. If participants pressed the wrong key (i.e. a key other than ‘x’ or ‘.’) the feedback ‘Wrong key’ was shown for 2 seconds prior to the next face appearing on the screen. If participants were too slow in responding (i.e. took longer than 4 seconds), the message ‘Too slow’ appeared on the screen. Otherwise no feedback was given. Since in the old/new recognition task there were 128 faces to consider, three participant breaks were incorporated. These allowed participants to rest their eyes after they had viewed 32 facial stimuli. At the end of the experiment participants were shown a further message thanking them for participating.

2.2.2 Results

In all the experiments reported in this chapter the analysis of the response latencies for the set of normal faces show speed effects that parallel those on accuracy, (which was my primary measure), thus faster performance in recognising upright normal faces compared to that for inverted. For the manipulated faces the response latencies in the upright and inverted conditions were very similar. Thus the mean latencies confirm the effects obtained by the accuracy scores. All the statistical tests in this chapter were conducted using SPSS and are two-tailed with an alpha of .05. I give the relevant F ratios and MSE, or the t value and the standard error for the effect tested. Simple effects analyses are uncorrected for multiple comparisons.

For completeness, the mean latencies for each condition in this experiment were (in msec): Normal Upright = 2176.69; Normal Inverted = 2286.59; Thatcherised Upright = 2283.72; Thatcherised Inverted = 2323.73. The data from all 32 participants were used in a signal detection analysis, where a *d'* of 0 indicates chance level performance. ANOVA revealed a significant effect of Face Type, *F*(1, 31) = 17.837, MSE = 0.209, p < .001, a significant effect of Orientation, *F*(1, 31) = 46.960, MSE = 0.205, p < .001 , and a significant interaction between Face Type and Orientation *F*(1, 31)= 4.739, MSE = 0.247, p = .037. The d' means for this analysis are shown in Figure. 2.2, which shows that the main effect of Face Type is due to performance on Normal faces being superior to that on Thatcherised ones, the main effect of Orientation is due to performance on Upright faces being superior to that on Inverted faces, and the interaction is due to there being a larger inversion effect for the Normal faces than for the Thatcherised ones. Simple effect analyses indicated that there was a strong inversion effect for normal faces, *t*(31) = 6.52, SE = 0.113, p < .001, and a similar (although smaller) inversion effect for Thatcherised upright vs. Thatcherised inverted faces, *t*(31) = 2.88, SE = 0.124, p = .007. To further investigate this result, the effect of face type on the recognition of upright faces was also analysed. Normal upright faces were recognised significantly better than Thatcherised upright faces *t*(31) = 5.59, SE = 0.095, p < .001, but there was no significant difference in the recognition of Normal inverted faces and Thatcherised inverted faces. Thus, it would seem that the reduction in the inversion effect for Thatcherised faces is more due to the impact that Thatcherisation has on the upright faces rather than on the inverted ones. In addition I analysed the performance relative to chance for each of the conditions in Experiment 1a. Performance for Normal faces was significantly above chance for both conditions; Upright *t*(31) = 22.19, SE = 0.076, p < .001, and Inverted *t*(31) = 8.51, SE = 0.113, p < .001. For Thatcherised faces performance was also significantly above chance in both conditions; *t*(31) =

12.30, SE = 0.095, p < .001, for Upright stimuli and *t*(31) = 8.20, SE = 0.099, p < .001 for Inverted ones.

Finally I am reporting here the SDT Bias estimates for each of the four stimulus' conditions: Normal Inverted, β= 1.385; Normal Upright, β= 2.281; Thatcherised Inverted, β= 1.531; Thatcherised Upright, β= 2.001.

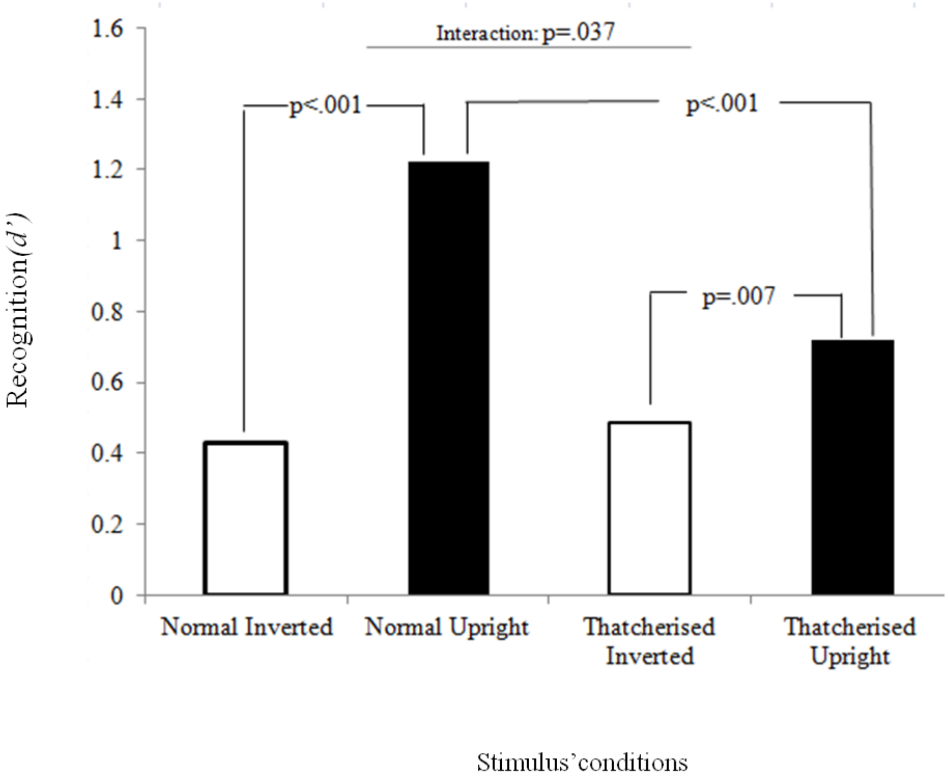


Figure.2.2 Results for the old/new recognition task. The X axis gives the four different stimulus' conditions, the Y axis shows the mean d' for each condition.

2.2.3 Discussion

In agreement with the existing literature on face recognition, the results of this first experiment have shown a clear effect of inversion for normal faces. In addition, there was a smaller inversion effect for Thatcherised faces, and the inversion effect for normal faces was significantly greater than that for Thatcherised faces. This confirmed that I can obtain a strong inversion effect, and that the magnitude of this effect can be reduced by Thatcherisation, which has the effect of disrupting second order relational information (among other things). This fits well with the argument that the inversion effect is based on the ability to exploit second order relational information for normal faces in an upright orientation. In Experiment 1b I replicated the design of Experiment 1a but this time with different stimuli that have been Thatcherised in a slightly different way. Thatcherisation in the literature is usually accomplished by one of two methods. The first is simple reflection (flipping) about a horizontal axis for the eyes and mouth, as in Experiment 1a of this chapter. The second is rotation of the eyes and mouth through 180°, which has similar, but discernibly different effects. I used this method of Thatcherisation in Experiment 1b to confirm that my particular pattern of results is not due to the specific manipulation used in Experiment 1a, as both manipulations should be equally effective at disrupting second order relational information.

2.3 EXPERIMENT 1b

2.3.1 Method

2.3.1.1 Materials

The study used 128 images taken from a different set of faces to that used in Experiment 1a. The faces were standardised to have a grey scale colour on a black background using Adobe Photoshop. Only male faces were used. This was to enable the hair to be cropped on each image without cropping the ears (i.e. males tend to have shorter hair with ears visible whereas females often have longer hair covering the ears). The faces were again manipulated using Gimp 2.6. However, this time the Thatcherised faces were produced by rotating the mouth and each of the eyes (individually) by 180 degrees. Any given face stimulus was presented in four different conditions i.e. normal upright, normal inverted, Thatcherised upright and Thatcherised inverted i.e. as it was in Experiment 1a. Examples of the stimuli used are given in Figure 2.3. The experiment was run using Superlab Version 4.0.7b installed on an iMac computer.

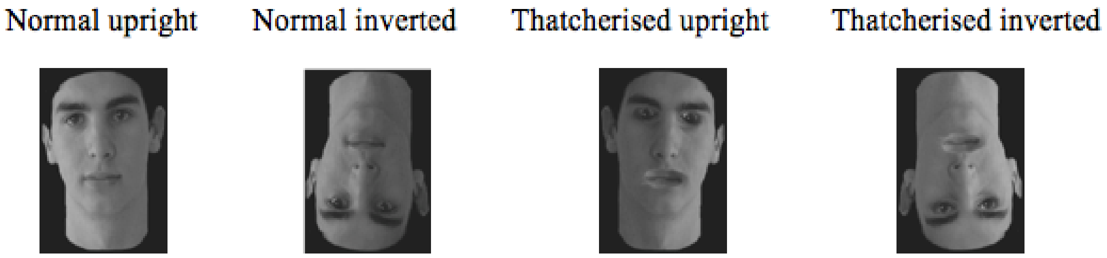


Figure.2.3. Examples of facial stimuli showing the four different conditions. The dimensions of the stimuli were 7.95cm x 6.28cm. The stimuli were presented at a resolution of 1920 x 1080. Participants sat 1m away from the screen on which the images were presented.

2.3.1.2 *Participants*

24 psychology undergraduates at the University of Exeter took part in the experiment. The study was counterbalanced, as in Experiment 1a, by splitting the participants into 8 groups.

2.3.1.3 Procedure

The procedure was exactly the same as that used in Experiment 1a. First, in the study phase, participants were asked to look at a set of faces shown on the computer screen one at a time in random order. Following this first phase of the experiment, the participants were presented with an old/new recognition task. The participants were told to press "." on the computer keyboard if they had seen the face before in the study phase, or "x" if they had not seen it before.

2.3.2 Results

The mean latencies for each condition used in the experiment were (msec): Normal Upright = 2456.92; Normal Inverted = 2523.91; Thatcherised Upright = 2516.33; Thatcherised Inverted = 2500.72. The data from all 24 participants were used in a signal detection analysis, where a *d'* of 0 indicates chance level performance. ANOVA revealed a significant effect of Face Type, *F*(1, 23) = 5.133, MSE = 0.236, p = .033, a significant effect of Orientation, *F*(1, 23) = 20.968, MSE = 0.300, p < .001 , and a significant interaction between Face Type and Orientation *F*(1, 23)= 5.214, MSE = 0.365, p = .032. The d' means for this analysis are shown in Figure. 2.4, which shows that the main effect of Face Type is due to performance on Normal faces being superior to that on Thatcherised ones, the main effect of Orientation is due to performance on

Upright faces being superior to that on Inverted faces, and the interaction is due to there being a larger inversion effect for the Normal faces than for the Thatcherised ones. Simple effect analyses indicated that there was a strong inversion effect for normal faces, *t*(23) = 4.985, SE = 0.159, p < .001. This time the inversion effect for Thatcherised upright vs. Thatcherised inverted faces was not significant, *t*(23) = 1.327, SE = 0.173, p = .197. To further investigate this result, the effect of face type on the recognition of upright faces was also analysed. Normal upright faces were recognised significantly better than Thatcherised upright faces *t*(23) = 3.097, SE = 0.164, p = .005, but there was no significant difference in the recognition of Normal inverted faces and Thatcherised inverted faces. Performance for Normal faces was significantly above chance for both conditions; Upright, *t*(23) = 8.609, SE = 0.142, p < .001, and Inverted *t*(23) = 3.573, SE = 0.120, p = .001. For Thatcherised faces performance was also significantly above chance in both conditions; *t*(23) = 4.899, SE = 0.146, p < .001, for Upright stimuli and *t*(23) = 3.630, SE = 0.134, p = .001 for Inverted ones.

Finally I am reporting here the SDT Bias estimates for each of the four stimulus' conditions: Normal Inverted, β= 0.894; Normal Upright, β= 1.721; Thatcherised Inverted, β= 1.443; Thatcherised Upright, β= 1.459.

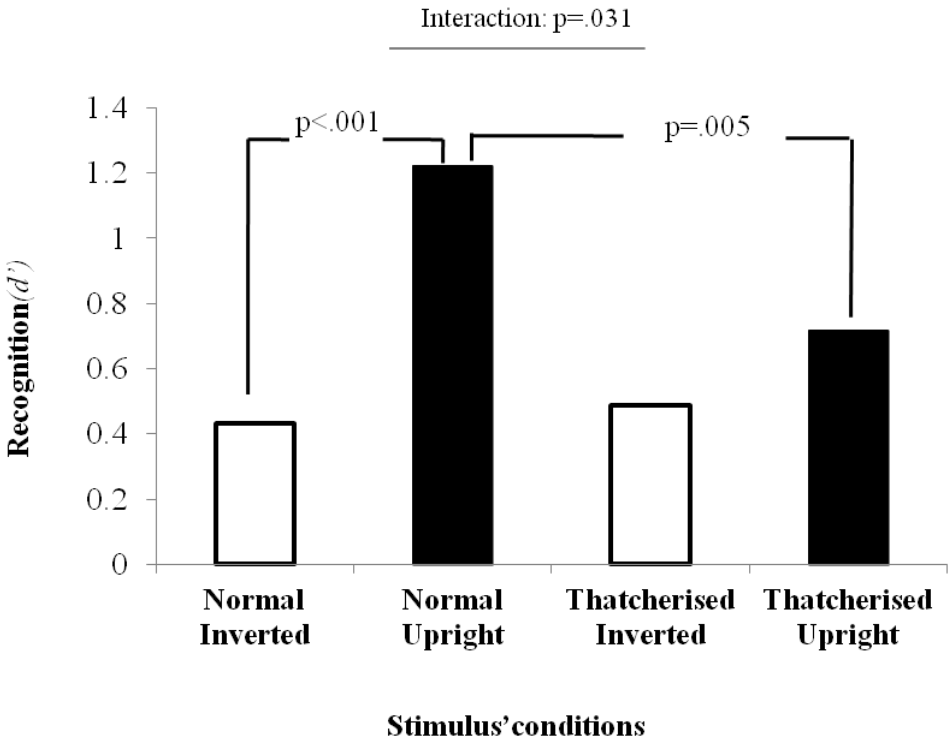


Figure.2.4.

Results for the old/new recognition task. The X axis gives the four different stimulus' conditions, the Y axis shows the mean d' for each condition.

2.3.3 Discussion

Experiment 1b has also revealed a strong effect of inversion for normal faces in line with the results of Experiment 1a. There was some reduction in the inversion effect for Thatcherised faces compared with that found in Experiment 1a, and this time the inversion effect for Thatcherised faces failed to reach significance, but there was a trend in that direction. Once again in Experiment 1b, the effect for normal faces was significantly greater than that for Thatcherised faces. Having established that I have a reliable effect in terms of our Orientation by Thatcherisation interaction, and also one that is robust to small changes in facial image and the manipulation used to Thatcherise the face, it was now possible to investigate the neurophysiological correlates of this effect. Experiment 1c uses the same procedures as Experiments 1a and 1b (and the set of male faces from Experiment 1b) to do just this.

2.4EXPERIMENT 1c

2.4.1 Method

2.4.1.1 Materials

The study used 320 images of faces in total, half female and half male. The male set of faces was the same as that used in Experiment 1b. The female set of faces was new, and it was standardised using a grey scale colour on a black background using Adobe Photoshop as for the male faces. This was to enable the hair and ears to be cropped on each image. The faces were again manipulated using Gimp. Both male and female faces were prepared in four different versions i.e. normal upright, normal inverted, Thatcherised upright and Thatcherised inverted. For the Thatcherised faces, the manipulation followed the same criteria used in Experiment 1b. Examples of male and female facial stimuli used are given in Figure 2.5. The experiment was run using E-prime software Version 1.1 installed on a PC computer.

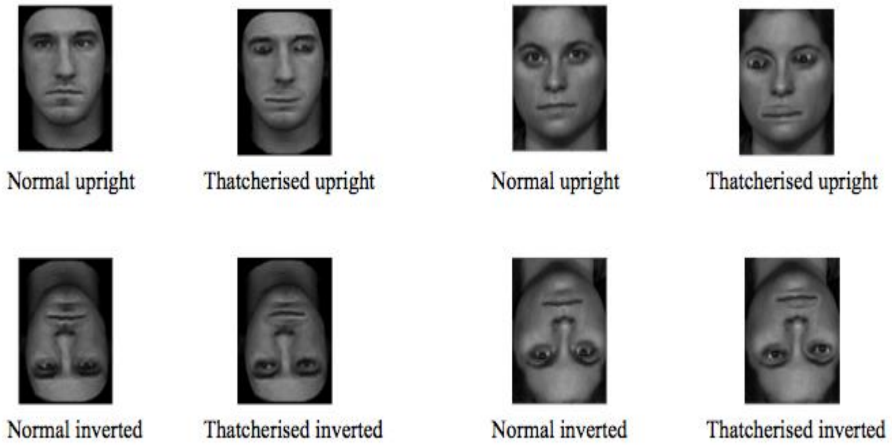


Figure.2.5. Examples of stimuli used in the experiment showing the four different conditions for male and female faces. The dimensions of the stimuli were 5.63cm x 7.84cm. The stimuli were presented at a resolution of 1280 x 960. Participants sat 1m away from the screen on which the images were presented.

2.4.1.2 Participants

32 undergraduates and postgraduates at the University of Exeter took part in the experiment.

2.4.1.3 Procedure

The experiment consisted of a ‘study phase’ and an ‘old/new recognition phase’ using only male faces, followed by another ‘study phase’ and ‘old/new recognition phase’, but this time using only female facial stimuli. After the instructions, the first part of the experiment involved participants looking at 80 male faces (presented one at a time in random order). The participants saw a fixation cross in the centre of the screen that was presented for 500 ms. This was followed by a black screen for 500 ms and then by a facial stimulus that was presented for 3000 ms. Then the fixation cross and the black screen were repeated, and another face presented, until all stimuli had been seen. These faces will be termed “familiar” (designated as type 1) faces for that participant because they will be presented again later on in the old/new recognition task. The face types during the study phase were: Normal Inverted faces (1NI); Normal Upright faces (1NU); Thatcherised Inverted faces (1TI) and Thatcherised Upright faces (1TU). Following the study phase, after further instructions, there was an old/new recognition task in which participants were shown (in random order) the 80 male faces they had already seen (i.e. the familiar faces) intermixed with a further 80 unseen male faces which were designated as type 2 (novel) and split into the same four face sub-types as the familiar set. During this old/new recognition task participants indicated whether or not they had seen the male face onscreen during the study phase by pressing the ‘.’ key If they recognised the face or by pressing ‘x’ if they did not. Each facial stimulus had a unique identifying number, to make sure that individual faces never appeared in more than one face type at a time during the experiment. To simplify their use in the experiment, the facial stimuli available were divided into sets of 20 giving 8 sets of stimuli, and each participant group was shown a different combination of the 8 sets of facial stimuli rotated over the 8 conditions in the experiment. Because there were 160 male faces to consider (80 in the study phase and 80 in the recognition task), four participant breaks were incorporated. These allowed participants to rest their eyes after they had viewed 40 faces. The second part of the experiment followed the same procedure as that used in the first part of the experiment. The only difference this time was that participants saw female faces.

2.4.2 EEG Apparatus

The EEG was sampled continuously during both the study and test phases at 500 Hz with a bandpass of 0.016-100 Hz, the reference at Cz and the ground at AFz using 64 Ag/AgClactive electrodes and BrainAmp amplifiers. There were 61 electrodes on the scalp in an extended 10-20 configuration and one on each earlobe. Their impedances were kept below 10 kΩ. The EEG was filtered offline with a 20 Hz low-pass filter (24 dB/oct) and re-referenced to the linked ears.

2.4.2.1 EEG Analysis

Peak amplitudes of the N170 in study and recognition phases were examined for differences between the experimental conditions. To improve the estimates of N170 amplitude and latency given the relatively small number of ERP segments in each condition (leading to a low signal-to-noise ratio), N170 extraction was aided by linear decomposition of the EEG by means of Independent Component Analysis (ICA, Bell & Sejnowski, 1995; for the application of ICA for the identification of ERP components, see Debener, Ullsperger, Siegel, Fieler, Von Cramon, & Engel, 2005, and Lavric, Bregadze, & Benattayallah, 2010). ICA is predicated on the assumption that the EEG at each electrode represents a mixture of temporally independent signals (components). It thus attempts to determine the ‘unmixing’ square matrix whose multiplication with the data results in the ‘original’ independent components. The number of entries for each dimension of the unmixing matrix is equal to the number of EEG electrodes, meaning that each row is a spatial filter that ‘unmixes’ one independent component from the EEG electrode data and the number of recovered components is equal to that of electrodes. Because the unmixing matrix relates electrodes to components, it is also referred to as ‘ICA weights’. An important aspect of the procedure is what constitutes the ‘independency’ of the extracted components. I used the Infomax version of ICA (Bell & Sejnowski, 1995; implemented in the Brain Analyzer software), which minimises the mutual information (maximises entropy) between components. Infomax comprises a neural network algorithm, with the EEG data at each electrode as input, a sigmoidal function of each independent component as output, and the unmixing matrix as the input-output connection weights. The algorithm iteratively adjusts the weights using gradient descent to maximise the entropy (independence) of the output (the components) (see Brown, Yamada, & Sejnowski, 2001).

ICA was run separately for each subject using all scalp channels and the entire dataset (not only the target ERP segments). The resulting ICA components were segmented into 600-ms epochs time-locked to stimulus onset and baseline-corrected relative to the mean amplitude in the 100 ms preceding the stimulus. For analyses of the recognition phase, segments associated with incorrect responses were discarded (there were no responses in the study phase). The remaining EEG segments were averaged for every participant and experimental condition. In each subject, we identified ICA components that: (1) showed a deflection (peak) in the N170 time-range (at 150-200 ms following stimulus onset), and (2) had a scalp distribution containing an occipital-temporal negativity characteristic of N170 (the scalp distributions of components are the columns of the inverted unmixing matrix). This resulted in 1-4 ICA components corresponding to the N170 identified in most subjects (mean 2.6; SD 1) - these were back-transformed into the EEG electrode space (by multiplying the components with the inverted unmixing matrix that had the columns corresponding to other components set to zero) and submitted to statistical analysis of N170 peak amplitude and latency.

2.4.3 Results

2.4.3.1Behavioural Results

The mean latencies for each condition used in the experiment were: Normal Upright = 1391.32; Normal Inverted = 1457.93; Thatcherised Upright = 1453.16; Thatcherised Inverted = 1479.47. The data from all 32 participants were used in a signal detection analysis, where a *d’* of 0 indicates chance level performance. ANOVA revealed a significant effect of Face Type, *F*(1, 31) = 7.314, MSE = 0.185, p = .011, a significant effect of Orientation, *F*(1, 31) = 32.421, MSE = 0.144, p < .001 , and a significant interaction between Face Type and Orientation *F*(1, 31)= 7.751, MSE = 0.146, p = .009. The d’ means for this analysis are shown in Figure. 2.6, which shows that the main effect of Face Type is due to performance on Normal faces being superior to that on Thatcherised ones, the main effect of Orientation is due to performance on Upright faces being superior to that on Inverted faces, and the interaction is due to there being a larger inversion effect for the Normal faces than for the

Thatcherised ones. Simple effect analyses indicated that there was a strong inversion effect for normal faces, *t*(31) = 5.369, SE = 0.107, p < .001, and a similar (although smaller) inversion effect for Thatcherised upright vs. Thatcherised inverted faces, *t*(31) = 2.426, SE = 0.081, p = .021. To further investigate this result, the effect of face type on the recognition of upright faces was also analysed. Normal upright faces were recognised significantly better than Thatcherised upright faces *t*(31) = 3.566, SE = 0.109, p = .001, but there was no significant difference in the recognition of Normal inverted faces and Thatcherised inverted faces. Thus, it would seem that the reduction in the inversion effect for Thatcherised faces is once again more due to the impact that Thatcherisation has on the upright faces rather than on the inverted ones. In addition I analysed the performance relative to chance for each of the conditions in Experiment 1c. Performance for Normal faces was significantly above chance for both conditions; Upright,*t*(31) = 8.835, SE = 0.099, p < .001, and Inverted *t*(31) = 4.406, SE = 0.068, p = .001. For Thatcherised faces performance was also significantly above chance in both conditions; *t*(31) = 6.583, SE = 0.073, p < .001, for Upright stimuli and *t*(31) = 4.794, SE = 0.099, p < .001 for Inverted ones.

Finally I am reporting here the SDT Bias estimates for each of the four stimulus' conditions: Normal Inverted, β= 1.032; Normal Upright, β= 1.563; Thatcherised Inverted, β= 1.261; Thatcherised Upright, β= 1.459.

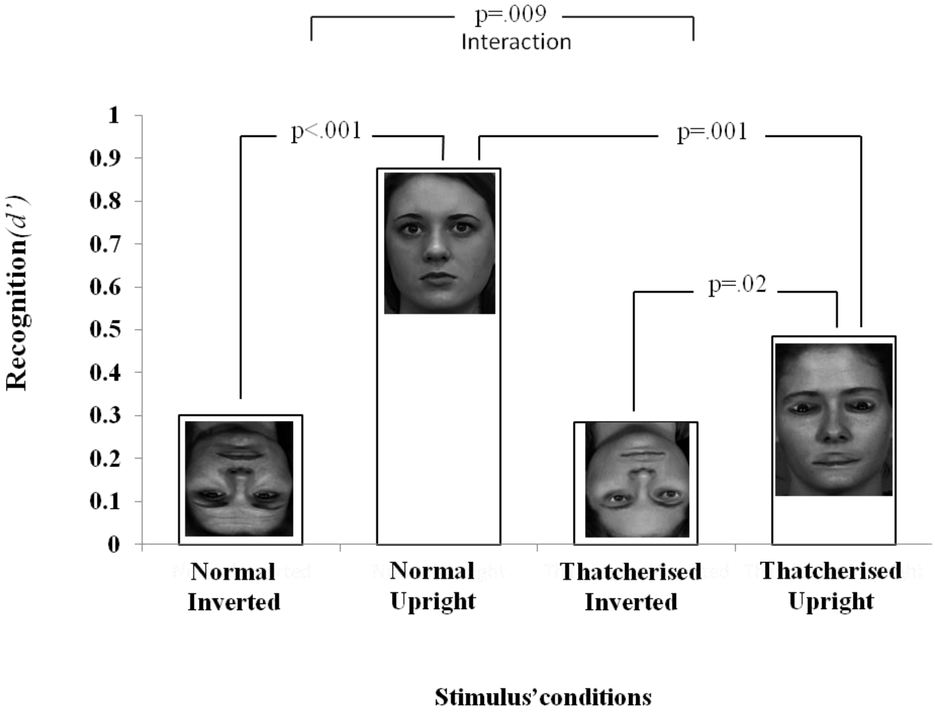


Figure.2.6. Results for the old/new recognition task. The X axis gives the four different stimulus' conditions, the Y axis shows the mean d' for each condition.

2.4.3.2 N170 analysis

Three participants had to be excluded because ICA did not find any components containing the N170 (nor was there an N170 visible in the original ERP). N170 latency and amplitude analyses were run in electrode PO8 as it was the one showing most of the activity during our experiment. I attempted to run the same analyses on the N170 data as on the *d'* behavioural data considered earlier to facilitate comparison.

2.4.3.3 Study phase (see Fig.2.7 and Table.2.2)

Latency analysis: ANOVA revealed a significant effect of Orientation, *F*(1, 28) = 12.339, MSE = 75.163, p = .002, and a significant interaction between Face Type and Orientation (because the effect of inversion on N170 latencies was reliably larger when faces were Normal compared to Thatcherised), *F*(1, 28) = 4.731, MSE = 49.005, p = .038. In particular, the effect was highly reliable for Normal faces, *t*(28) = 4.603, SE = 1.842, p < .001, with N170 latencies peaking 9 ms earlier for upright faces (at 165 ms) compared to inverted faces (174 ms). For Thatcherised faces, peaks for inverted faces were delayed compared to upright faces by only 3 ms. This delay did not reach significance, *t*(28) = 1.244, SE = 2.273, p = 0.223. Latencies of upright faces peaked earlier (by 4 ms) when faces were Normal compared to Thatcherised. This difference was only marginally reliable, *t*(28) = 1.803, SE = 1.836, p = .082.

Peak amplitude analysis: ANOVA revealed that there were no significant main effects (Fs<1), but that there was a significant interaction between Face Type and Orientation, thus the difference in peak amplitudes between upright and inverted faces was significantly larger when faces were Normal (-0.46μV) than when they were Thatcherised (0.002μV), *F*(1, 28) = 4.18, MSE = 0.382, p = .05. The effect of inversion was reliable for Normal faces, *t*(28) = 2.657, SE = 0.175, p = .012, with more negative amplitudes for inverted (-0.513μV) compared to upright (-0.046μV) faces. For Thatcherised faces the inversion effect did not approach significance *t*(28) = 0.011, SE = 0.241, p = .991. The effect of Face Type was marginally reliable for upright faces,*t*(28) = 1.957, SE = 0.206, p = .06, with more negative amplitudes for Thatcherised (-0.451μV) compared to Normal (-0.046μV) faces.

2.4.3.4 Old/new recognition task (see Fig.2.8 and Table.2.2)

Latency analysis: ANOVA revealed a main effect of Face Type, *F*(1, 28) = 5.205, MSE = 22.286, p = .03, and a main effect of orientation, *F*(1,28) = 17.391, MSE = 38.862, p < .001, but this time there was no significant interaction between face type and orientation *F*(1, 28) < 1 , MSE = 28.108, p = .677. A significant inversion effect was obtained for normal faces *t*(28) = 4.045, SE = 1.295, p = .001 with N170 latencies peaking 5 ms earlier for upright faces (at 163 ms) compared to inverted faces (168 ms). A significant inversion effect was found for Thatcherised faces *t*(28) = 2.574, SE = 1.714, p = .016 with N170 latencies peaking at almost 5 ms earlier for upright Thatcherised faces (at 165.31 ms) compared to inverted (169.72 ms). A planned comparison revealed a numerical trend that did not reach significance for upright normal stimuli compared to Thatcherised upright ones *t*(28) = 1.507, SE = 1.601, p = .143.

Peak amplitude analysis: ANOVA showed a main effect for orientation, *F*(1, 28) = 5.274, MSE = 0.69, p = .029. As for latencies, no reliable Orientation by Face Type interaction was found. Means show a numerical trend for Normal faces, with more negative amplitudes for inverted (-0.73μV) vs. upright (-0.39μV), *t*(28)

= 1.584, SE = 0.216, p = .13. For Thatcherised faces amplitudes are reliably more negative when they are inverted (-0.91μV) vs. upright (-0.54μV), *t*(28) = 2.144, SE = 0.170, p = .041.

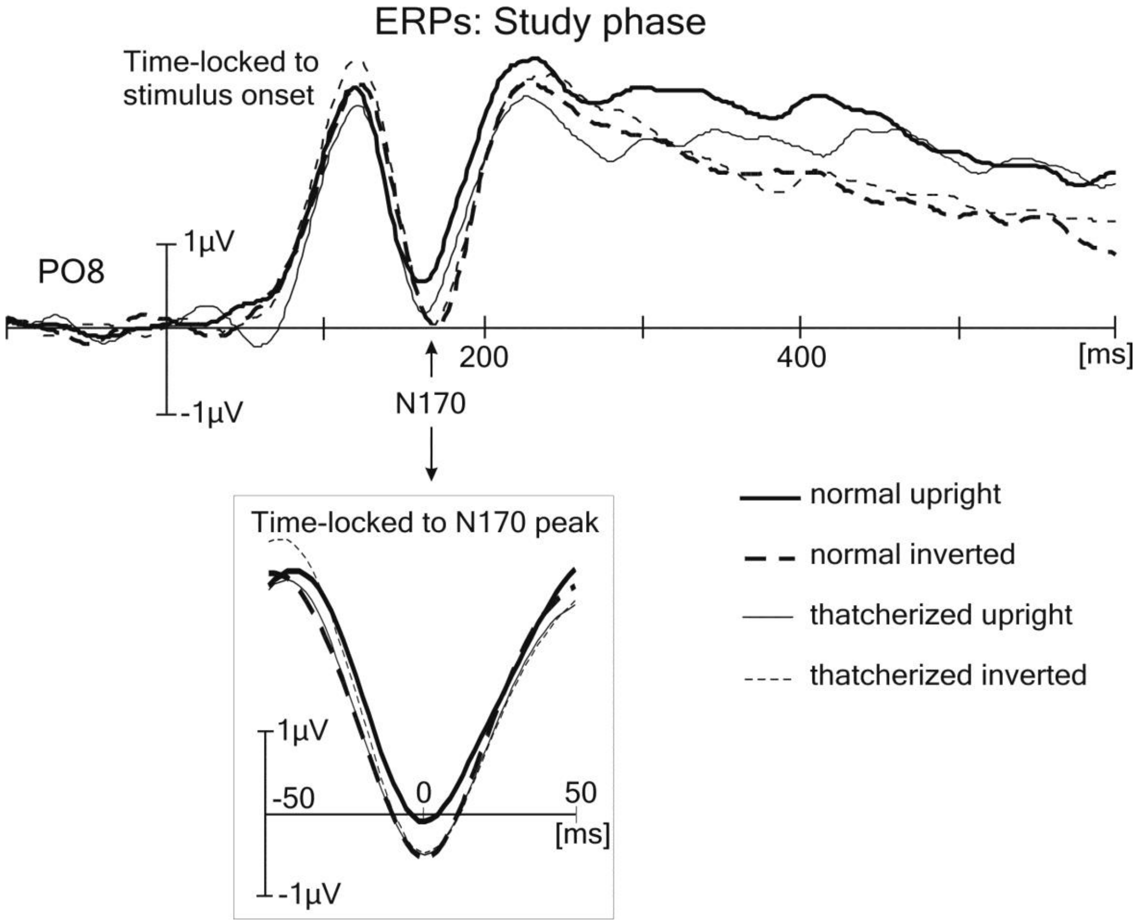


Figure.2.7. The X axis shows the elapsed time after a stimulus was presented, whereas the Y axis shows the amplitudes (μV) of the electrophysiological reactions in the study phase of the experiment. The insert in this figure is the ERP time-locked to the N170 peak, as identified in individual subjects. The time-scale of the inserts is stretched relative to the main stimulus-locked ERPs, the amplitude scale is the same in the insert as in the main figure.

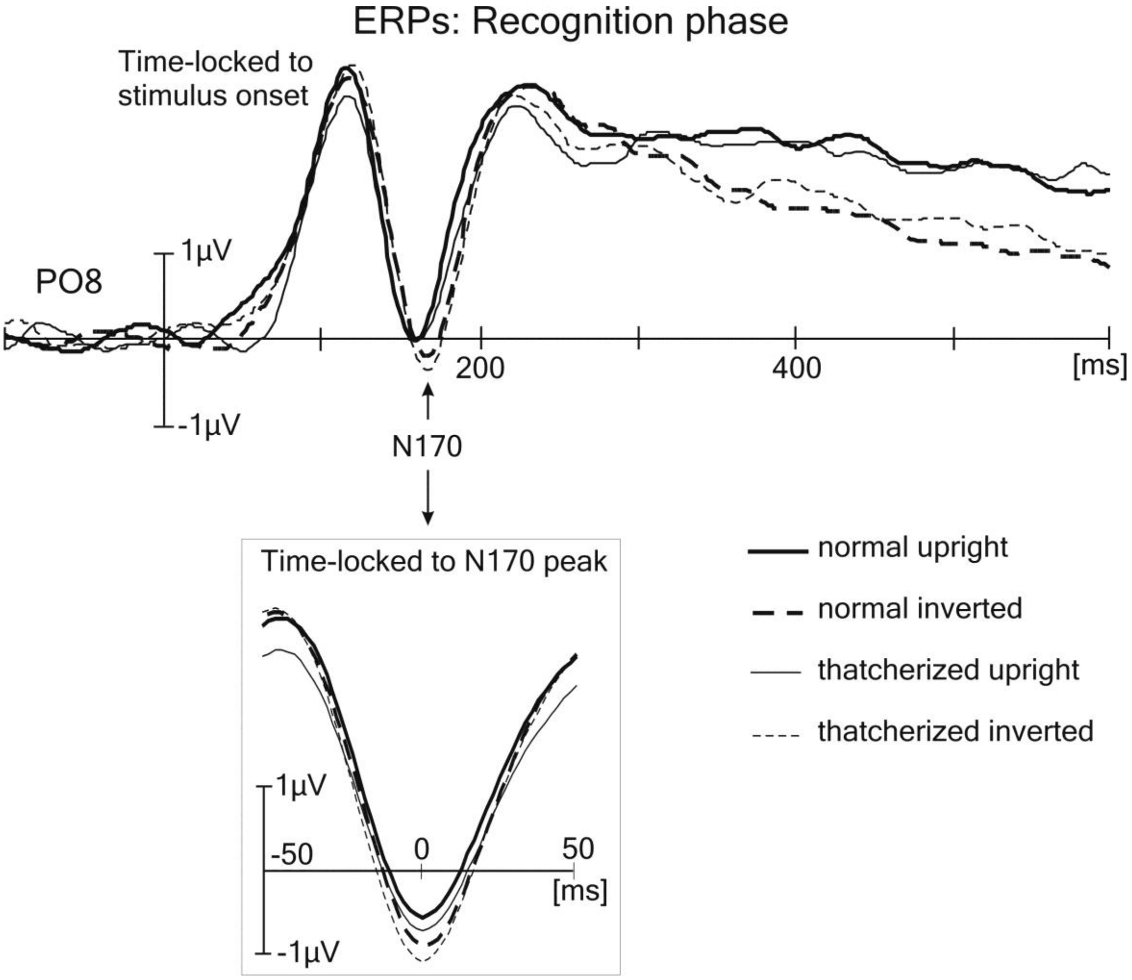


Figure.2.8.The X axis shows the elapsed time after a stimulus was presented. The Y axis shows the amplitudes (µV) of the electrophysiological reactions in the old/new recognition phase of the experiment.

Supplemental **Table 2.2** *Amplitude and latency values of the N170.*

	Study Phase				***Old/New Recognition task***			
Stimulus type	**Normal**		**Thatcherised**		**Normal**		**Thatcherised**	
	Upright	Inverted	Upright	Inverted	Upright	Inverted	Upright	Inverted
Latencies (ms) PO8 (Right)	168.562	172.375	171.937	170.875	159.187	161.062	162.312	161
Amplitudes[µV] PO8 (Right)	-0.072	-0.558	-0.025	-0.093	0.007	-0.002	-0.165	0.122

2.4.4 Discussion

This Experiment 1c has, in essence, confirmed my predictions. On the behavioural side I have obtained a strong inversion effect for normal faces and a reduced one for Thatcherised faces consistent with what I had previously found in Experiments 1a and 1b. The ERP results provide the correlates of the behavioural findings in the study phase where participants were only asked to look at the faces and try to memorise them. Analyses on both the amplitude and latency show a larger inversion effect on the N170 for normal faces than for Thatcherised faces. Running the same planned comparisons on the ERP data as for the behavioural data produces a very similar pattern of results, i.e. a strong inversion effect for the normal faces, a reduced effect for the Thatcherised faces, and a difference in N170 amplitude between the upright normal and Thatcherised faces but not between the two face types when inverted.

2.5 General Discussion

The behavioural results of this chapter show that I have obtained a significant inversion effect with normal faces, and have demonstrated that it is significantly larger than the inversion effect obtained with Thatcherised faces. To some extent, then, this confirmed the basic face inversion finding. According to Diamond and Carey's (1986) theory, the most straightforward explanation of the difference in performance to the two face types when upright is that the Thatcherised faces have lost some (but not all) of the benefit of our expertise in dealing with second order structure. Because the Thatcherised faces are still essentially faces, then the application of our expertise with normal faces may lead to positively unhelpful results for upright Thatcherised faces, in that the changed features stand out and command processing. Because these features are not those best suited to individuate faces, i.e. our processing is being dominated to a greater extent by what is common to Thatcherised faces (because they are surprising) rather than what would aid us in discriminating between them, performance for upright Thatcherised faces would be expected to be worse than for normal upright faces. The lack in Experiment 1a, 1b and 1c, of any significant difference in recognition performance between normal and Thatcherised faces when inverted can be explained by arguing that in these circumstances second order relational information is not in play, and the two types of face are otherwise equated in terms of features and other factors (e.g. overall shape of the face).

The results from the ERPs bolster this interpretation of the effects obtained in the behavioural results. As was predicted, the N170 to upright normal faces was different to that of my other stimuli, an effect that it can now be argued reflects in part the high degree of expertise participants had for them. One of the findings here is that this difference was a great deal clearer in the study phase of the experiment than in the test phase. This is not an entirely unexpected result. Firstly, if the modulation of the N170 reflects an effect of expertise, then this should occur when simply perceiving the stimulus – the effect is not tied to having to do anything in particular, except perhaps attend to the stimulus itself. Secondly, as a result of the study phase, the Thatcherised stimuli will start to become familiar and, as a consequence, the Thatcherised upright faces will tend to become progressively more equivalent to normal upright faces. Thus, any effect in the study phase will be a relatively pure comparison of the two stimulus types, one highly familiar, the other novel (at least in part); but in the test phase this distinction, and the effects that flow from it, will be attenuated by participants' increasing familiarity with the Thatcherised stimuli. If we study the waveforms that are time-locked to stimulus onset then the pattern at the N170 exactly corresponds to that observed in the behavioural data. As predicted, the N170 for upright normal faces occurs earlier and with smaller amplitude, that for upright Thatcherised faces is somewhat later and has greater amplitude, and both the inverted face types are slightly later still and have slightly greater amplitude than upright Thatcherised faces. The suggestion is that the N170 is indexing, at least in part, the effect of expertise with the stimulus category. Inversion of the faces increases the amplitude of the N170 and delays its onset in agreement with a number of other studies which have found a greater delay and larger amplitude for the inverted stimulus (Rossion *et al*, 2002; Tanaka and Curran, 2001; de Haan *et al*, 2002).

However, I note that there are a few issues with this explanation based on Diamond and Carey's (1986) hypothesis. The first issue with this explanation is that on inversion the Thatcherised faces have some of the second order structures as normal because now the eyes and mouth are both the right way up. Thus, if the FIE would be expected to be solely based on an effect of expertise for second order relations I should have obtained superior performance for Thatcherised inverted faces compared to normal inverted ones.

A second (and perhaps the main) issue is that the FIE for the Thatcherised stimuli is still strongly significant in Experiments 1a and 1c, and there is a clear trend in 1b, suggesting that simply disrupting second order information does not completely eliminate the FIE. Some explanations for this can be given: **(i)** By rotating the eyes and the mouth I have not disrupted all the second order information in a face. Thus, the Thatcherised stimuli still have some second order information which participants may have some expertise for: **(ii)** Perhaps it is not only second order information that is involved in the FIE but there may be an important role for other types of configural information. It may be that by disrupting both first and second order relational information I would be able to eliminate the FIE entirely: **(iii)** The final potential explanation is that actually the fact that I rotated half of the features upside down may have disrupted participants' expertise for each of those features in its usual orientation, thus a more featurally-based account of the FIE would follow, which would be in some agreement with other studies on the FIE (see McKone and Yovel for a review 2009) .

McKone and Yovel (2009) made a strong case for the role of local feature information in the FIE by conducting a meta-analysis that indicated that the inversion effect was not entirely due to changes in the processing of configural information contingent on inversion, but instead depended, in part at least, on the orientation of individual features. They evaluated the claim that perception base on local feature information shows no or weak inversion effects, and found that the evidence does not support this claim. Instead they argued that local feature information can make a contribution to the FIE that is the equal of that due to the processing of configural information. This position is strongly supported by Rakover and Teucher's (1997) finding that it is possible to obtain an inversion effect even with facial features presented in isolation, suggesting that configural information is not necessary to obtain such an effect. Indeed, Rakover and Teucher go further, and claim that the FIE could simply be due to some non-linear combination of the effects resulting from the inversion of local features, and not depend on configural information at all.

The claims about the magnitude of the inversion effect in this chapter are secure, but I am unable to tell to what extent performance in all the conditions is still benefiting from the effects of expertise (all the stimuli are, after all, recognisable as faces). What I can conclude, however, is that Thatcherisation interacts with stimulus inversion in a way that strongly suggests that we are better able exploit some type of information present in upright facial stimuli. However, the assertion that the second order structures are the only type of information critical for the FIE does not seem to be as secure. In the next chapter of this thesis I tried to address some of the issues listed here. In particular, I investigated the contribution that configural information and featural information make to the FIE. Starting from the position that, if configural information and hence second order relations are the only relevant information driving the FIE, then by disrupting this information entirely I must be able to demonstrate a strong reduction in the FIE, to the point where it too should have disappeared entirely.

Chapter 3: Parts and Wholes: Individual features and their configurations

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3.1 Introduction to the experiments

The experiments that follow seek to determine whether or not configural facial information plays a vital role in the FIE, testing the proposition that without it, there would be no inversion effect for faces. In Experiment 2a, I aimed to demonstrate the typical strong inversion effect for normal face stimuli, and for comparison purposes ran a condition using scrambled faces as stimuli, in which I kept the features in their normal orientation, but quasi-randomly distributed them across the face. These latter stimuli suffer from strongly disrupted configural information (even when upright), which should entirely eliminate any effect of inversion on recognition for these stimuli if the FIE depends on this type of information. They also have the useful characteristic of being well matched for complexity with the normal faces. However I need to note that my manipulations find agreement with the original definition of configural information provided by Diamond and Carey (1986). Thus, if I was able to entirely eliminate the inversion effect by using scrambled faces this would be evidence consistent with Diamond and Carey’s (1986) position. If, instead, the FIE is still present for scrambled faces, then I can say that strong disruption of configural information is not enough to eliminate the FIE, casting doubt on its supposedly pre-eminent role in driving this effect.

3.2 Experiment 2a

3.2.1 Method

3.2.1.1 *Materials*

The study used 128 images of faces that were standardised to a grey scale colour on a black background using Adobe Photoshop. Only male faces were used. This was to enable the hair to be cropped on each image without cropping the ears, as males tend to have shorter hair with the ears visible whereas females often have longer hair covering the ears making this feature rather variable. In addition, all the faces had a neutral facial expression. The faces were manipulated using Gimp 2.6. Scrambled faces were constructed so as to conform to a prototype, i.e. a particular configuration, but not the normal one that our participants would be familiar with. Six facial features were used for creating the scrambled exemplars i.e. the mouth, nose, two ears and the two eyes (including eyebrows). Scrambling was performed by selecting one feature of the face at random and then moving it to the forehead (chosen because this is the widest space inside the face and so can accommodate any feature). Following this, a second feature was selected at random and moved to the space left empty by the first feature, and so on until all the 6 facial features had been moved. All the exemplars I constructed and presented to a given participant shared a particular arrangement of the features (i.e. the features were selected and moved in a given order), but of course varied in the features themselves as they were based on different original faces.

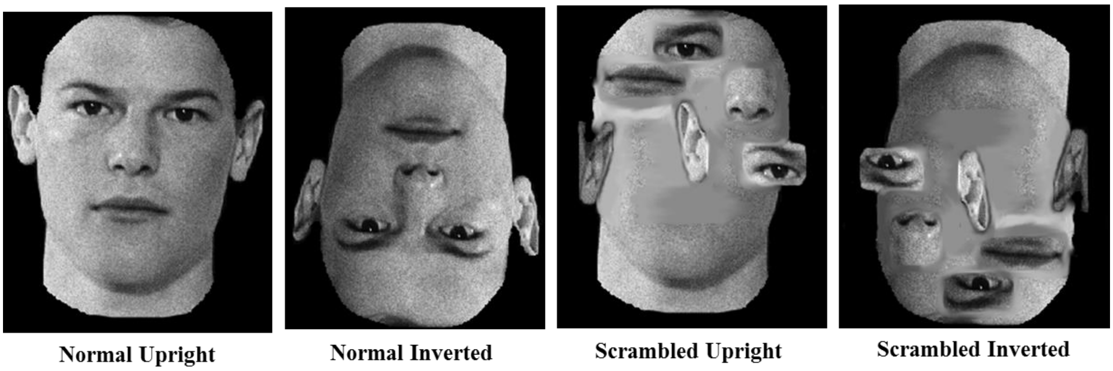


Figure.3.1. Examples of stimuli used in Experiment 2a of this chapter 3 showing the four different conditions. The dimensions of the stimuli were 7.95cm x 6.28cm. The stimuli were presented at a resolution of 1920 x 1080. Participants sat 1m away from the screen on which the images were presented.

3.2.1.2 Participants

The participants were 24 (16 female and 8 male) psychology undergraduates at the University of Exeter. The study was counterbalanced by splitting the participants into 8 groups. Each participant group was shown the same 128 faces, but each group saw each face in a different condition.

3.2.1.3 Procedure

The study consisted of a ‘study phase’ and an old/new 'recognition phase’, and was in large part the same as the experiments presented in Chapter 2. For the convenience of the reader I will briefly outline the procedure used here. After the instructions, the procedure had participants look at 64 different faces (presented one at a time in random order) during the study phase. After further instructions, participants were then asked to look at 128 facial stimuli (including the 64 already seen) again presented in a random order. During this old/new recognition task participants indicated whether or not they had seen the face during the study phase. In the study phase each participant was shown 4 types of face with 16 photos for each face type (giving a total of 64 faces). These faces will be termed the “familiar” faces for that participant. The face types were: Normal Inverted faces; Normal Upright faces; Scrambled Inverted faces and Scrambled Upright faces. In the test phase another 64 novel faces split into the same four face types were added to this set. Each facial stimulus had a unique identifying number, to make sure that individual faces never appeared in more than one condition at a time during the experiment. To simplify their use in the experiment, the facial stimuli available were divided into sets of 16, giving 8 sets of stimuli, and each participant group was shown a different combination of the 64 facial stimuli split over the 8 sets. Each participant saw the facial stimuli corresponding to their participant group in a different order. The first event that participants saw after the instructions consisted of a warning cue (a fixation cross in the centre of the screen) presented for 1 second. This was followed by a face, presented for 3 seconds, then the fixation cross was repeated and another face presented until all 64 facial stimuli had been seen. Once all 64 faces were shown, the programme moved to the next set of instructions, which explained to participants the nature of the old/new recognition task. Participants were told that they were about to see more faces presented one at a time in random order. They were asked to press the ‘.’ key if they recognised the face or to press ‘x’ if they did not. Each participant within each participant group was then shown (in a random order) the 64 faces they had already seen intermixed with a further 64 unseen faces. These unseen faces were those from the sets of facial stimuli not used during the study phase.

During the old/new recognition task, after the warning cue (1 second), facial stimuli were shown for 4 seconds and participants had to respond during this period. If participants pressed the wrong key (i.e. a key other than ‘x’ or ‘.’) the feedback ‘Wrong key’ was shown for 2 seconds prior to the next face appearing on the screen. If participants were too slow in responding (i.e. took longer than

4 seconds), the message ‘Too slow’ appeared on the screen. Otherwise no feedback was given. Since in the old/new recognition task there were 128 faces to consider, three participant breaks were incorporated. These allowed participants to rest their eyes after they had viewed 32 facial stimuli. At the end of the experiment participants were shown a further message thanking them for participating.

3.2.2 Results

As in Chapter 2 all the experiments reported in this Chapter 3 the analysis of the response latencies for the set of normal faces show speed effects that parallel those on accuracy, (which was my primary measure), thus faster performance in recognising upright normal faces compared to that for inverted. For all the sets of manipulated faces the response latencies in the upright and inverted conditions were very similar. The mean latencies for each condition used in the experiment were: Normal Upright = 2345.30; Normal Inverted = 2475.85; Scrambled Upright = 2649.89; Scrambled Inverted = 2652.08. The data from all 24 participants were used in a signal detection analysis, where a *d’* of 0 indicates chance level performance. Each p-value reported in this chapter is for a two-tail test, and I also report the F or t value and a suitable measure of variability for each statistic.

ANOVA revealed a significant effect of Face Type, *F*(1, 23) = 15.16, MSE = 0.339, p = .001, a significant effect of Orientation, *F*(1, 23) = 18.71, MSE = .450, p = .001, and a significant interaction between Face Type and Orientation *F*(1, 23) = 8.512, MSE = 0.045, p = .008 . The d’ means for this analysis are shown in Figure 3.2, which shows that the main effect of Face Type is due to performance on Normal faces being superior to that on Scrambled ones, the main effect of Orientation is due to performance on Upright faces being superior to that on Inverted faces, and the interaction is due to there being a larger inversion effect for the Normal faces than for the Scrambled ones. Simple effect analyses indicated that there was a strong inversion effect for normal faces, *t*(23) = 4.733, SE = 0.189, p < .001, and a reduced inversion effect for Scrambled faces, *t*(23) = 1.895, SE = 0.156, p = .084. In addition, I ran comparisons comparing performance on upright faces, and inverted faces. Performance in recognizing Normal Upright faces was significantly better than recognition for Scrambled Upright faces, *t*(23) = 5.276 , SE = 0.146, p < .001, but performance on inverted faces was not reliably affected by scrambling. In addition I analysed the performance relative to chance for each of the conditions in Experiment 1a. Performance for Normal faces was significantly above chance for both conditions; Upright, *t*(23) = 8.926, SE = 0.154, p = .001, and Inverted *t*(23) = 3.277, SE = 0.145, p = .003. For Scrambled faces performance was also significantly above chance in both conditions; *t*(23) = 5.119, SE = 0.118, p = .001, for Upright stimuli and *t*(23) = 2.689, SE = 0.120, p = .013 for Inverted ones.

Finally I am reporting here the SDT Bias estimates for each of the four stimulus' conditions: Normal Inverted, β= 0.978; Normal Upright, β= 1.801; Scrambled Inverted, β= 1.076; Scrambled Upright, β= 1.468.

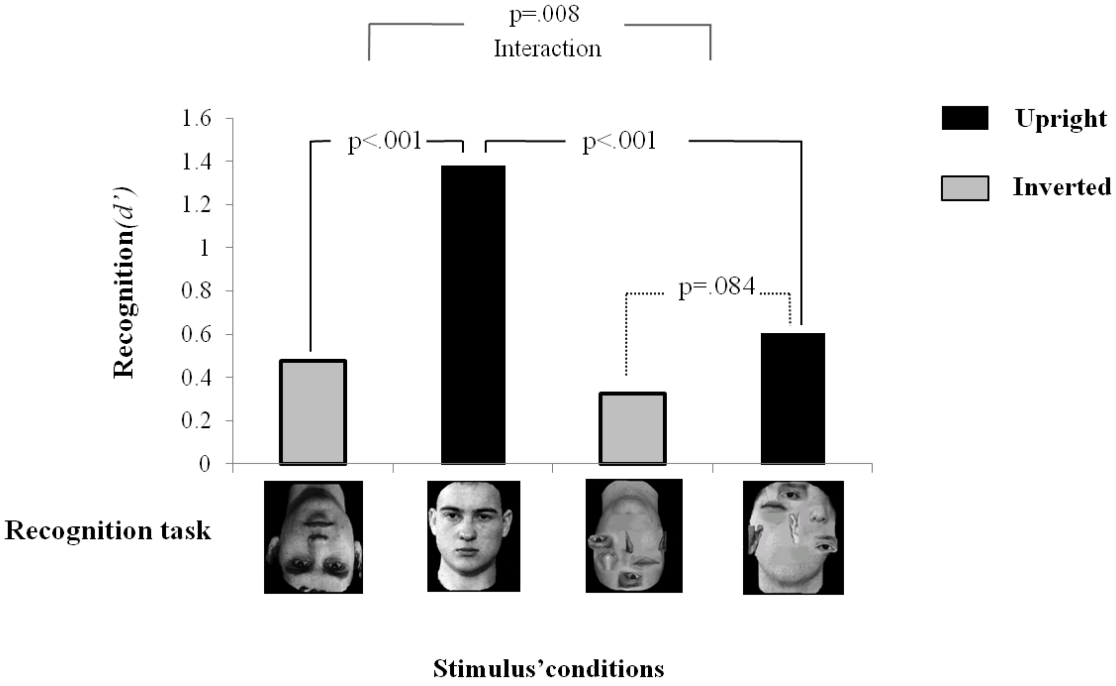


Figure.3.2. The X axis represents the four different stimulus conditions (in order, from left to right, Normal Inverted, Normal Upright, Scrambled Inverted and Scrambled Upright), and the Y axis gives the mean d' for each of the four facial conditions in the old/new recognition phase of Experiment 2a.

3.2.4 Discussion

Consistent with the existing literature on face recognition, the results of this first experiment have shown a clear effect of inversion for normal faces. In addition, there was a smaller, near significant inversion effect for Scrambled faces, and the inversion effect for normal faces was significantly greater than that for Scrambled faces. These results are certainly consistent with McKone and Yovel's (2009) analysis, however, according to Diamond and Carey's (1986) analysis the FIE for the Scrambled faces should have been entirely eliminated by the complete disruption of their configural information. My results seem to suggest that disrupting all the configural information is not enough to eliminate the FIE, but, frustratingly, fall short of complete clarity on this point. At this juncture I considered how best to improve on Experiment 2a to obtain an unequivocal answer to the question of whether the FIE is, in part, driven by local feature information.

There are only a few studies in the literature that have investigated the effect of scrambling on the inversion effect, and these do not really have the potential to answer my question. As an example, Collishaw and Hole (2000) used sets of scrambled faces in their study in which the eyes were always moved as a configuration either to the upper half of the face or to the lower half. Thus, the first and second-order relational information between the eyes was always preserved. The same applied to the nose and the ears, which were always moved together, thus, for these three features the configural information was unaltered. Finally, a significant issue with their manipulation was that, on average, all the scrambled faces were not based on a single new configuration, but many different ones. Thus, they do not share a configuration in the same way that the normal faces do. My set of scrambled faces control for this, and my manipulation also ensures that all the configural information is disrupted. But I realised that there was still at least one potential issue with our stimuli. If we compare normal faces with scrambled, it is very obvious that the scrambled faces have been smoothed as part of the scrambling process, and so have lost some of the shadows and local information that may be salient in aiding recognition. The normal faces have not been smoothed at all, and still have all their local information. If we are to truly compare the inversion effect for Normal and Scrambled faces this needs to be controlled for. Another possible issue is that I have constructed our set of scrambled stimuli around one new configuration. It may be that participants may have found it quite easy (or alternatively quite hard) to recognise this particular category of scrambled faces in their upright orientation. A better approach would be to have more categories of scrambled faces to counterbalance across my participants groups in order to reduce any systematic error in the estimate of the inversion effect for the scrambled faces. Experiment 2b aimed to fix these issues.

3.3 Experiment 2b

3.3.1 Method

3.3.1.1 *Materials*

This time I constructed four categories of scrambled faces each represented by a particular configuration as shown in Figure 3.3. The scrambling was done following the same procedure used in Experiment 2a, and within the same category all the scrambled faces shared the arrangement of the features in common with the prototype. Thus, for example, each face drawn from category A had the nose, mouth etc. in the locations shown. The subjects in this experiment were presented with stimuli drawn from only one category of scrambled faces. The four categories were counterbalanced across the eight participant groups. Finally, the normal faces were also smoothed to the same extent as the sets of scrambled faces in order to control for any effect of this manipulation.

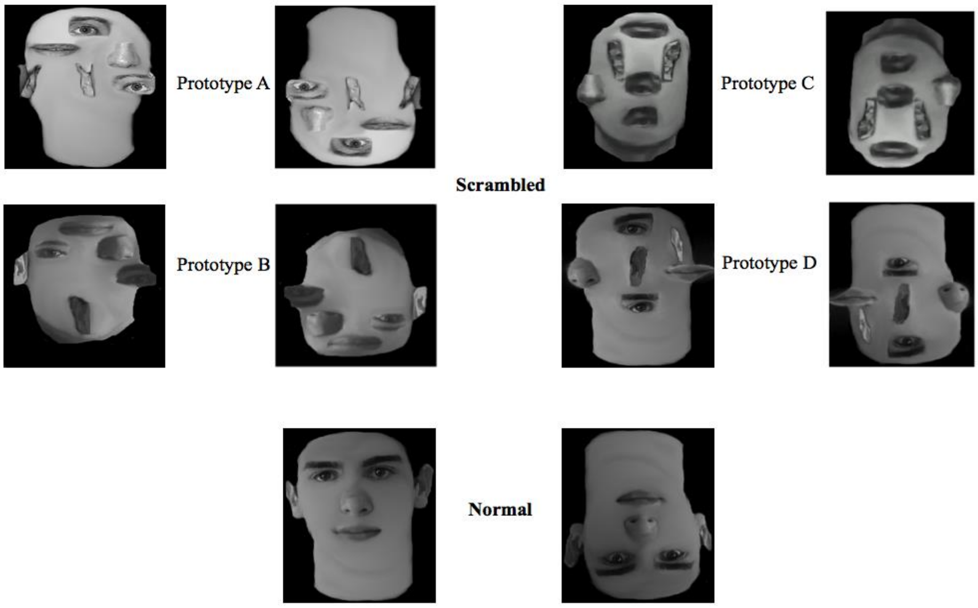


Figure.3.3. This figure shows the four prototype-defined categories of scrambled faces in pairs (upright then inverted), plus an example of the set of normal faces at the bottom illustrating the effect of smoothing compared to the normal faces used in Experiment 2a.

3.3.1.2 Participants

24 (18 female and 6 male) psychology undergraduates at the University of Exeter took part in the experiment. The study was counterbalanced, as in Experiment 2a, by splitting the participants into 8 groups.

*3.3.1.3*Procedure

These were exactly the same as in Experiment 2a.

3.3.2 Results

The mean latencies for each condition used in the experiment were: Normal Upright = 2448.63; Normal Inverted = 2576.24; Scrambled Upright = 2594.44; Scrambled Inverted = 2592.94.The data from all 24 participants were used in a signal detection d' analysis. ANOVA revealed a main effect of Face Type, *F*(1, 23) = 12.79, MSE = .272, p = .002, and a main effect of orientation, *F*(1, 23) = 8.15, MSE = .424, p = .009, but this time there was no significant interaction between Face Type and Orientation *F*(1, 23) < 1, p = .536. Figure 3.4 gives the mean d' for each face type. Despite the lack of a significant interaction simple effects were run to allow comparison with Experiment 2a, and these showed that there was an inversion effect both for Normal faces, *t*(23) = 2.323, SE = 0.188, p = .029, and for Scrambled faces, *t*(23) = 2.412, SE = 0.132, p = .025. As in Experiment 2a, performance in recognising Normal Upright faces was significantly better than recognition for Scrambled Upright faces, *t*(23) = 3.051, SE = 0.144, p = .005, and this time there was also a significant difference in the recognition of Normal Inverted faces and Scrambled Inverted faces, *t*(23) = 2.285, SE = 0.140, p = .031, with Scrambled Inverted faces recognised worse, but note that this is a post-hoc comparison that would not survive a Bonferroni correction. Performance for Normal faces was significantly above chance for both Upright, *t*(23) = 5.712, SE = 0.145, p = .001, and Inverted faces, *t*(23) = 3.092, SE = 0.127, p=.005. For the Scrambled faces, performance was significantly above chance for the Upright stimuli *t*(23) = 4.491, SE = 0.087, p < .001, but not significantly above chance for the Inverted ones, *t*(23) = 0.677, SE = 0.107, p = .505. I note that this last result could raise concerns about a floor effect for our Scrambled Inverted condition, but as this would simply make it difficult to assay any difference between this condition and others near floor, and in fact all the other conditions were significantly superior to this one, there is little cause for concern.

Finally the Bias estimates for each of the four stimulus' conditions are: Normal Inverted, β= 1.045; Normal Upright, β= 1.687; Scrambled Inverted, β= 1.032; Scrambled Upright, β= 1.065.

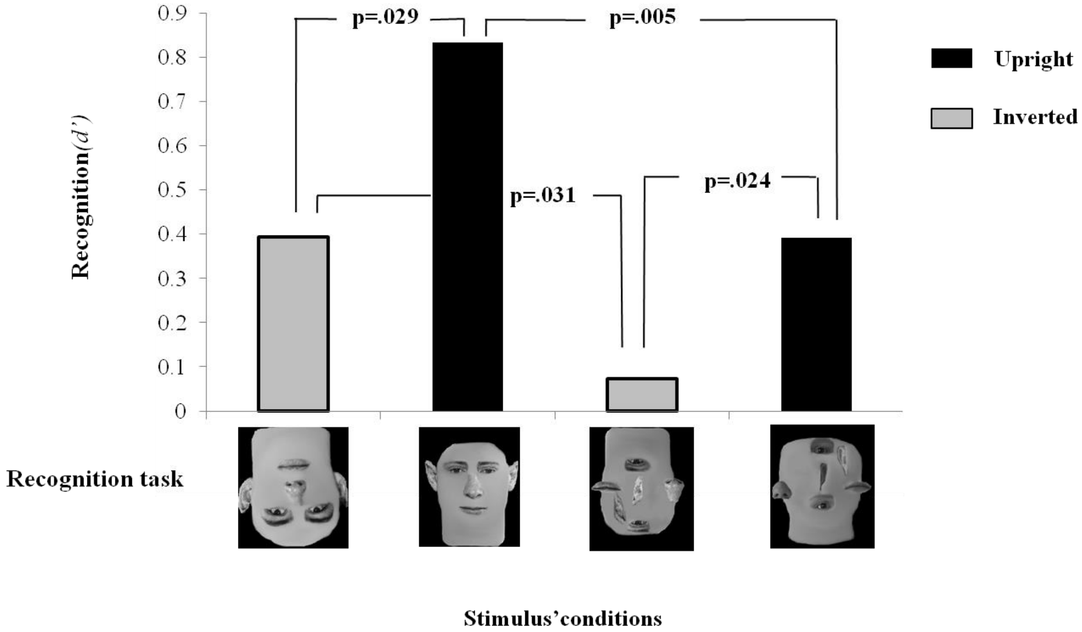


Figure.3.4.The X axis gives the four different stimulus conditions (from left to right; Normal Inverted, Normal Upright, Scrambled Inverted and Scrambled Upright), each illustrated by a typical exemplar, and the Y axis shows the mean d' for each of the four facial conditions in the old/new recognition phase of Experiment 2b.

3.3.3 Discussion

Contrary to the predictions derived from Diamond and Carey's (1986) theory, the results from Experiments 2a and 2b can now be said to establish that disrupting all the configural (i.e. first and second order relational information) information in a face does not eliminate the FIE. In the case of Experiment 2b, there is as reliable a FIE for scrambled faces as for (smoothed) normal faces, confirming the trend for an inversion effect in the scrambled faces previously shown in Experiment 2a. I believe that there are good reasons for why this happened. Firstly, the smoothing of the normal faces on the one hand helped in matching the two face types, and in so doing I may well have lost some recognition performance for the upright normal faces because they now have less information in them than before smoothing. This goes some way to explaining why there is no Face Type by Orientation interaction in Experiment 2b, because the inversion effect for normal faces was itself reduced. The upshot of this improved stimulus control is that the scrambling manipulation can now tell us the size of the FIE for normal faces relative to that obtained when all configural information is disrupted, and the surprising result I have is that the FIE for scrambled faces is as strong (the effect size for scrambled faces is slightly smaller, but overall performance is down as well so that relatively speaking a case could be made for it being somewhat underestimated) as the one for normal faces. A final point is to note that both normal inverted and upright faces are recognised significantly better than their scrambled counterparts. Thus, the disruption of configural information has definitely been effective in reducing overall performance, but this has not been at the expense of the FIE. I will come back to this point in the general discussion. The main finding makes it clear that configural information is not the only source contributing to the FIE. Instead, following Rakover and Teucher (1997), I can now agree that featural information has an important role to play in generating the FIE. When we consider upright scrambled faces, clearly they have all the configural information (in the sense implied by Diamond and Carey's 1986 analysis) disrupted by scrambling, but the orientation of each facial feature is still upright (and hence in its familiar orientation). This is not true of inverted scrambled faces – can I show that this is the basis of the inversion effect I have found in Experiments 2a and 2b? In the next experiment I investigated this proposition by asking whether the disruption of the *single feature orientation information* by rotation could entirely eliminate the FIE.

Another reason for testing the effect of this manipulation was that at this point I felt that there were two possibilities remaining. It could be that inversion does disrupt the ability to process the configural information contained within a face, and that this is the basis of the face inversion effect, but this disruption occurs irrespective of one's familiarity with the configuration in question. The idea here would be that once "face parts" were identified, specialised mechanisms for processing their configuration could be called upon and would confer an advantage in later recognition, a type of "holistic" processing (Mondloch &Maurer, 2008). This type of account would be consistent with theories that take the position that faces are special, and that there are regions of the brain (e.g. the FFA) dedicated to processing face-type stimuli (cf. Kanwisher, 2000). Another possibility is that the inversion effect is a direct product of the individual features of the face, and that their configuration is simply irrelevant. All that matters is how many upright features there are. This explanation in terms of a direct effect of individual feature orientation would also allow an expertise-based account, because the expertise would now be for the individual features in their upright orientation, not for any information based on their configuration. Both these accounts agree that the orientation of the individual features will be crucial in determining any inversion effect, and that if there are an equal number of features in both upright and inverted orientations in an "upright" stimulus then no inversion effect can be expected, i.e. performance in either stimulus orientation should be equal. Intriguingly, however, they would appear to differ in their predictions for how scrambled faces which have had the orientation of individual features manipulated would fare relative to upright or inverted scrambled faces. If identification of face parts engages some specialised mechanism for processing faces, and in particular if the outline or shape of the face assists in this, then we would expect our manipulated faces to be as good as upright scrambled faces. But, if it is simply a matter of each individual feature conferring an advantage if it is upright, then I might expect my manipulated faces to be somewhat better than inverted scrambled faces, but somewhat worse than upright scrambled faces.

3.4 Experiment 3

3.4.1 Method

3.4.1.1 Materials

In this experiment I once again used the four categories of scrambled faces employed in Experiment 2b, but this time I turned half of the features for each face upside down. Specifically, for each of the four category prototypes I inverted one of the eyes, one of the ears and one of either the nose or the mouth. As was the case in the previous experiment, each scrambled face drawn from a given category had the location and orientation of its features specified by its category prototype. Because half of the features were now presented upside down and half in their usual upright orientation I have named these new stimuli 50% Feature-Inverted and Scrambled faces, but acknowledge that they possess a close relationship with Thatcherised faces. Recall that, in the original Thatcher illusion study by Thompson (1980), three features were also upside down, but Thompson (1980) always inverted the two eyes and the mouth to produce his Thatcherised faces. However, for my purposes there are two issues with that manipulation: (i) As I have already mentioned in the general discussion of Chapter 2, the inversion of the two eyes together would still maintain the normal configural relations between them and recognition performance might be affected by this; (ii) if only featural information is involved in the FIE then several studies have shown that the eyes are perhaps the most salient features in face processing (Haig, 1986; Hosie, Ellis, & Haig, 1988). When the eyes are concealed, face recognition is poorer than when they are visible (Haig, 1986). Also the eyes are described more frequently than other facial features when participants describe faces (Ellis et., 1979). Thus, it may be that inverting both eyes when the configural information is entirely disrupted in the scrambled condition could have more of an effect than turning just one eye upside down, even if the number of features that are inverted and upright in the stimulus are equal. My chosen manipulation is somewhat different, and I believe it controls for these potential issues, in that I use scrambled faces (which addresses issue (i) because I scramble the features independently), and I only inverted one of the eyes, effectively controlling for issue (ii). The result of my manipulation is a set of stimuli that quite obviously differ from those used in Experiment 2b (see Fig.3.5). The same set of normal faces used in Experiment 2b was used in this experiment as well. Thus, in this experiment I had four within-subject conditions, Normal faces in an Upright or Inverted orientation, and 50% Feature-Inverted and Scrambled Faces in either an Upright or an Inverted orientation.

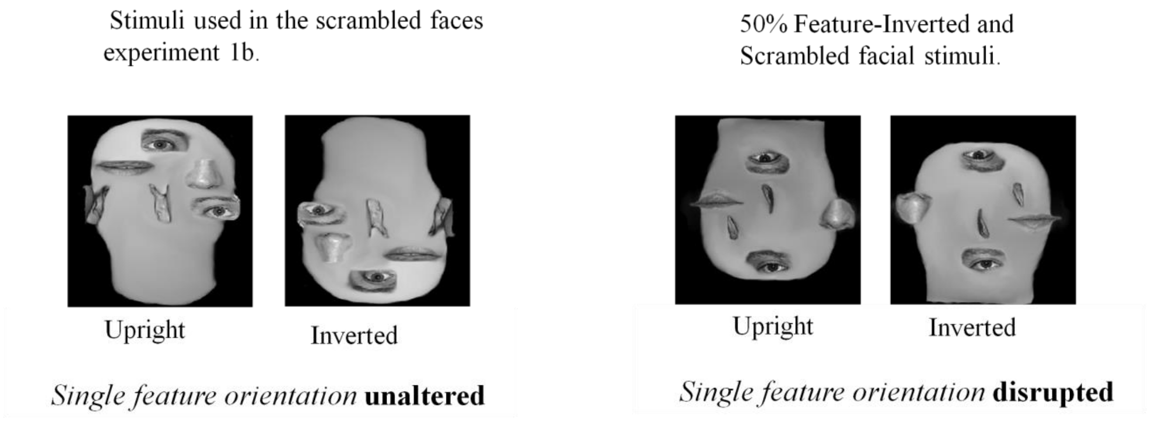


Figure.3.5. Comparison of the stimuli used in Experiment 2b (on the left side) and the stimuli used in Experiment 3 (on the right side). These latter ones were manipulated by inverting half of the features.

*3.4.1.2*Participants

48 (35 female and 13 male) students at the University of Exeter (mostly psychology students) took part in the experiment. I used a larger N because pilot testing indicated that participants found the 50% Feature-Inverted and Scrambled faces particularly difficult to recognise. The study was counterbalanced, as in Experiment 2a, 2b by splitting the participants into 8 groups.

*3.4.1.3*Procedure

This was exactly the same as that used in Experiment 2b, with the proviso that 50% Feature-Inverted and Scrambled faces replaced the scrambled faces used in Experiment 2b.

3.4.2 Results

As in the other experiments reported in this chapter, I give the mean latencies for each condition which were: Normal Upright = 2404.30; Normal Inverted = 2479.03; 50% Feature-Inverted and Scrambled Upright = 2634.34; and 50% Feature-Inverted and Scrambled Inverted = 2624.18. The data from all 48 participants were used in the signal detection d' analysis. ANOVA revealed there was a significant main effect of Face Type, *F*(1, 47) = 31.02, MSE = 0.390, p < .001, a significant main effect of orientation, *F*(1, 47) = 26.24, MSE = 0.150, p < .001, and a significant interaction between face type and orientation, *F*(1, 47) = 5.963, MSE = 0.020, p = .018 (see Fig.3.6). Thus, simple effect analyses were conducted showing that there was a strong inversion effect for normal faces, *t*(47) = 5.327, SE = 0.086, p < .001, but no reliable inversion effect was obtained for 50% Feature-Inverted and Scrambled faces, *t*(47) = 1.164, SE = 0.095, p = .250. Performance in recognizing Normal Upright faces was significantly better than recognition for 50% Feature-Inverted and Scrambled Upright faces, *t*(47) = 5.405, SE = 0.125, p < .001, and there was also a significant difference in the recognition of Normal Inverted faces compared to 50% Feature-Inverted and Scrambled Inverted faces (which were worse), *t*(47) = 3.136, SE = 0.104, p = .002. Performance for Normal Upright and Normal Inverted faces were both significantly above chance, *t*(47) = 11.046, SE = 0.083, p < .001, and *t*(47) = 6.243, SE = 0.074, p < .001. Finally, to check that participants were not suffering from a floor effect, I demonstrated that both upright and inverted 50% Feature-Inverted and Scrambled faces were recognised significantly better than chance, Upright, *t*(47) = 3.312, SE = 0.074, p = 001, Inverted, *t*(47) = 2.093, SE = 0.65, p = .041 (see Fig.3.6).

Finally the Bias estimates for each of the four stimulus' conditions are: Normal Inverted, β= 0.914; Normal Upright, β= 1.308; 50% Feature-Inverted Scrambled Inverted faces, β= 1.108; 50% Feature-Inverted Scrambled Upright faces, β= 1.206.

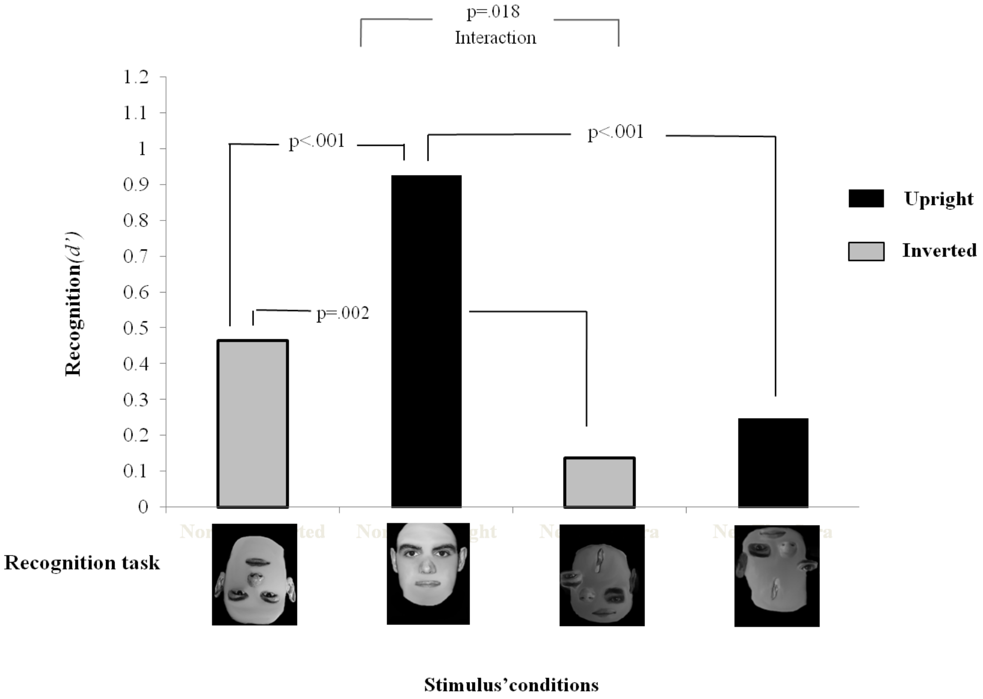


Figure.3.6.The X axis represents the four different stimulus conditions (in order, from left to right, Normal Inverted, Normal Upright, 50% Feature-Inverted and Scrambled Inverted and 50% Feature-Inverted and Scrambled Upright), and the Y axis gives the mean d' for each of the four facial conditions in the old/new recognition phase of Experiment 3.

3.4.3 Discussion

The results from Experiment 3 demonstrate the importance that single feature orientation information has in generating the FIE. I am now able to entirely eliminate the inversion effect by disrupting single feature orientation information within the context of a scrambled face, whilst maintaining performance for my 50% Feature-Inverted and Scrambled stimuli at a level significantly above chance. In some sense I felt that I had to obtain this result, as with six features, of which three are now inverted, whether the face is upright or inverted, three of the individual features are in their upright orientation. But this is to disregard the effect that the outline or envelope of the face could have had, as if this were used to determine whether a face was perceived as upright or inverted then my result would not necessarily follow. In other words, if what I have termed an upright 50% Feature-Inverted and Scrambled face were actually perceived as upright, and hence subject to specialized processing on the basis that it was a face, I might have expected an inversion effect to emerge. Because it did not, I can conclude that the individual features in a scrambled face (including the ears in this designation) are primary in determining any inversion effect and reject at least some versions of the holistic processing account of the FIE.

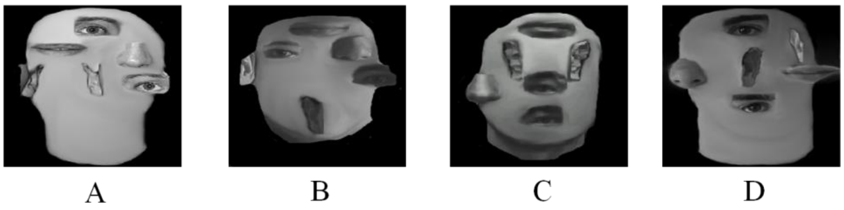
The logical next step in order to replicate and confirm the importance of single feature orientation in the FIE was to compare the inversion effect obtained with scrambled faces to the lack of one for 50% Feature-Inverted and Scrambled faces. The prediction was that if the FIE is mainly based on single feature orientation, then, within a single experiment, I should be able to show a significantly greater FIE for scrambled faces compared to 50% Feature-Inverted and Scrambled stimuli.

3.5 Experiment 4

3.5.1 Method

*3.5.1.1*Materials

In this experiment I used the four categories of scrambled faces already used in Experiment 2b and the four categories of 50% Feature-Inverted and Scrambled faces used in Experiment 3. Hence, Scrambled and 50% Feature-Inverted and Scrambled exemplars drawn from the same category have the same arrangement of features in common. Stimuli were counterbalanced in such a way that each participant was always presented with one configuration of scrambled faces and a different configuration of 50% Feature-Inverted and Scrambled faces.


Scrambled faces

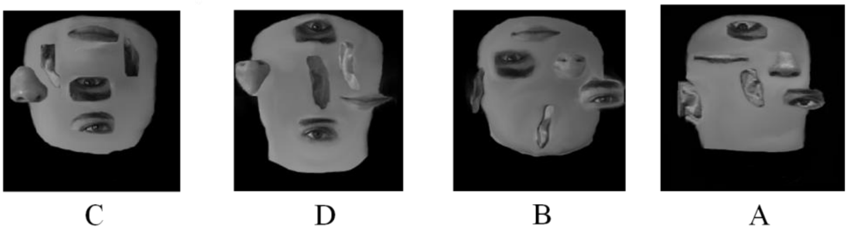

50% Feature-Inverted and Scrambled faces

Figure.2.7.This shows the four configurations of scrambled faces and the four configurations of 50% Feature-Inverted and Scrambled faces used in Experiment 4.

*3.5.1.2*Participants

72 (53 female and 19 male) students at the University of Exeter (mostly psychology students) took part in the experiment. I used a large number of participants because the task was likely to be considerably more difficult than in the previous experiments given that all the faces were now scrambled.

*3.5.1.3*Procedure

These were the same as before.

3.5.2 Results

Mean latencies for each condition were: Scrambled Upright = 2626.02; Scrambled Inverted = 2615.63; 50% Feature-Inverted and Scrambled Upright = 2618.48; and 50% Feature-Inverted and Scrambled Inverted = 2573.68. The data from all 72 participants were used in the signal detection d' analysis. ANOVA revealed that there were no significant main effects (Fs < 1), but that there was a significant interaction between Face Type and Orientation, *F*(1, 71) = 9.396, MSE = 0.015, p = .003 (see Fig.3.8). Thus, simple effects analyses were carried out showing that there was a strong inversion effect for Scrambled faces, *t*(71) = 3.349, SE = 0.084, p = .001, but no inversion effect for 50% Feature-Inverted and Scrambled faces, *t*(71) = 1.027, SE = 0.095, p = .308. Additional comparisons revealed that performance in recognizing Scrambled Upright faces was significantly better than recognition for 50% Feature-Inverted and Scrambled Upright faces, *t*(71) = 2.391, SE = 0.082, p = .019, and that

50% Feature-Inverted and Scrambled Inverted exemplars were recognised significantly better than Scrambled inverted exemplars, *t*(71) = 2.089, SE = 0.087, p = .040. Performance for Scrambled Upright faces was significantly above chance, *t*(71) = 6.564, SE = 0.061, p < .001, and performance for Scrambled Inverted faces approached significance *t*(71) = 1.935 , SE = 0.063, p = .055. Finally, both upright and inverted 50% Feature-Inverted and Scrambled faces were recognised significantly better than chance, Upright, *t*(71) = 3.182, SE = 0.064, p = .002, Inverted, *t*(71) = 4.377, SE = 0.069, p < .001 (see Fig.3.8).

Finally the Bias estimates for each of the four stimulus' conditions are: Scrambled Inverted, β= 1.133; Scrambled Upright, β= 1.120; 50% Feature-Inverted Scrambled Inverted faces, β= 1.103; 50% Feature-Inverted Scrambled Upright faces, β= 1.054.

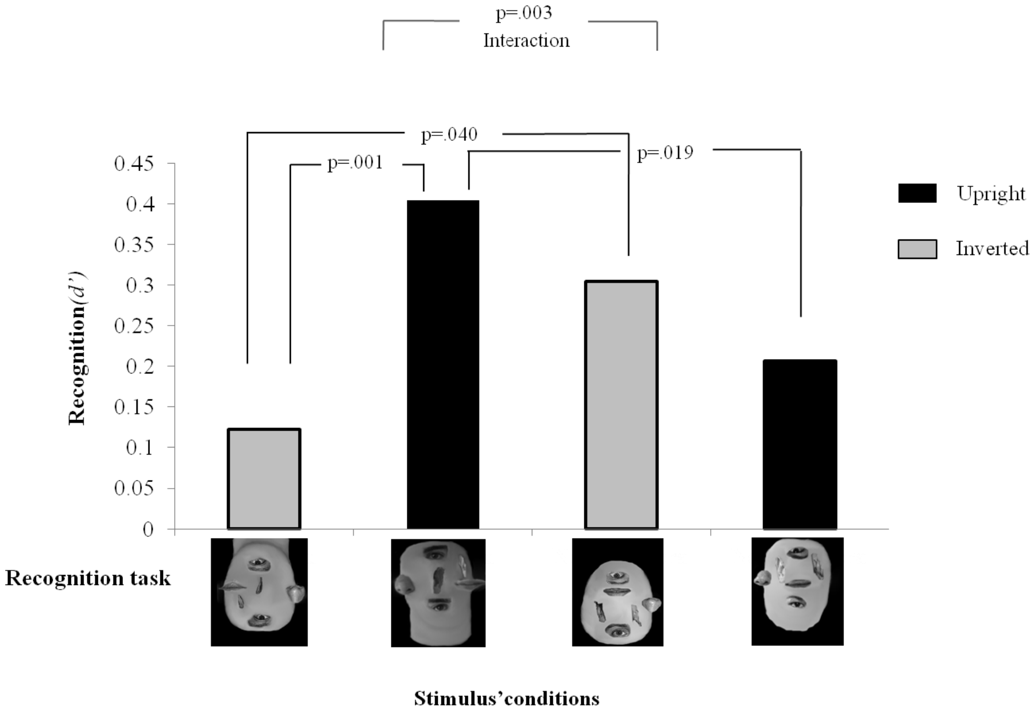


Figure.3.8.The X axis represents the four different stimulus conditions (in order, from left to right, Scrambled Inverted, Scrambled Upright, 50% Feature-Inverted and Scrambled Inverted and 50% Feature-Inverted and Scrambled Upright), and the Y axis gives the mean d' for each of the four facial conditions in the old/new recognition phase of Experiment 4.

3.5.3 Discussion

In Experiment 4 I obtained a significant interaction driven by a strong inversion effect for the scrambled faces and no inversion effect for the 50% Feature-Inverted and Scrambled stimuli. These results confirmed that I am able to obtain a strong inversion effect for a set of faces that have all their configural information disrupted, but that the FIE can be entirely eliminated by disrupting single feature orientation information in these scrambled faces. It would seem that inverted features are less beneficial than upright ones. Upright scrambled faces have 6 upright isolable features, upright and inverted 50% Feature-Inverted and Scrambled faces have three upright isolable features, and inverted scrambled faces have no upright features of this kind. Thus, the pattern of performance in these data can be simply explained by the proportion of upright features in the set of faces in question. The reason that inverted scrambled faces are so difficult to recognise according to this analysis is that all their features are upside down, which hampers them relative to inverted 50% Feature-Inverted and Scrambled faces (3 features upright) and leads to a strong inversion effect compared to upright scrambled faces (6 upright features). Thus, the claim would be that the inversion effect in scrambled faces is entirely driven by the proportion of upright features in the stimulus, irrespective of location or configuration, a position entirely in line with that adopted by Rakover and Teucher (1997).

3.6 General Discussion

In this chapter, I investigated the contributions made by configural and featural information to the FIE. Experiments 2a and 2b investigated the link between configural information and the FIE. Remarkably, Experiment 2b showed that disruption of all configural information of the type considered in Diamond and Carey's analysis (both first and second order) was effective in significantly reducing recognition performance, but did not significantly impact on the FIE. Experiments 3 and 4 revealed that face processing is affected by the orientation of individual features, and that this plays a major role in producing the FIE. The FIE was only completely eliminated when I disrupted the *single feature orientation information* in addition to the configural information, by using a new type of transformation similar to Thatcherising the sets of scrambled faces. The results from this chapter clearly support the claim made by Rakover and

Teucher (1997) that single features contribute to the inversion effect. In their studies they looked at single features presented in isolation in either an upright or inverted orientation. They found that recognition performance was superior for the upright stimuli. My studies complement and enhance Rakover and Teucher's findings because I presented the individual features all together in a novel configuration. This has the advantage of addressing an issue with Rakover and Teucher's (1997) procedure, in that presenting a single feature (NB. They considered both eyes to be a single feature) may allow participants to imagine it as belonging to a normal face, and it may be the memory for this imagined face that leads to the inversion effect, as I would expect this strategy to be more effective for upright features. My novel configurations do not lend themselves to this strategy, but still give rise to an inversion effect. My experiments, then, are a direct experimental test of the hypothesis advanced by McKone and Yovel (2009) that there is a substantial component of the inversion effect due to local feature orientation, and my results strongly support their conclusion, based on a meta-analysis of 22 papers, that this is indeed the case.

In addition, the results from Experiment 4 showed a clear advantage for scrambled faces in an upright orientation compared to upright 50% Feature-Inverted and Scrambled faces, and a disadvantage for inverted scrambled faces compared to inverted 50% Feature-Inverted and Scrambled ones. The advantage can be easily explained by assuming that expertise for each of these features in their usual orientation brought about by our extensive experience with faces is beneficial. In some sense, the disadvantage then follows from this analysis as well. If having a feature in its upright orientation is beneficial, then we can assume that when inverted some or all of this benefit is lost. It may even be that inverted features drawn from stimulus sets we are familiar with incur a penalty that makes them harder to recognise than unfamiliar control stimuli, as McLaren's (1997) work with chequerboards might suggest.

Which brings me to the question of whether it is possible to demonstrate any role for configural information in generating the inversion effect for faces? There is a great deal of evidence reviewed in the introduction of this thesis consistent with the proposition that it does, but the logic behind the experimental results obtained in Chapter 3 of this thesis suggests the answer is "no". I confess to being reluctant to draw such a firm conclusion on the basis of the experiments reported up to this point. The results of Chapter 3 go somewhat beyond what McKone and Yovel (2009) might expect, in that they were willing to allow a component of face inversion due to configural information. I also note that the experiments reported in Chapter 3 are much better suited to establishing that individual feature orientation plays a role in generating the inversion effect than proving that configural information does not. Thus in the next chapter I aimed to answer the question: Does configural information affect the FIE?

Chapter 4: Does configural information affect the FIE? The role of first-order and second-order relational information

4.1 Introduction to the experiments

If, in my hands, the results from experiment, 2b and 4 clearly showed that scrambling does not greatly affect the inversion effect, can I show that it has any effect at all on the FIE? If we look at Experiment 2b and compare the normal inverted faces with the scrambled inverted ones, both sets of faces have all their isolable features upside down. However, the scrambled faces also have all their configural information disrupted, and performance on them is significantly worse. There is a similar effect for upright normal and scrambled faces. Equally, in Experiment 3, we can see that inverted 50% Feature-Inverted and Scrambled faces are still recognised worse than normal inverted faces, and that a similar effect obtains for upright faces. A possible explanation of the advantage for normal faces is that they do still have their configural information. This suggests that configural information is more important for overall performance rather than being specific to the FIE. There is a main effect of Face type (Normal vs. either Scrambled or 50% Feature-Inverted and Scrambled) in Experiment 2a, $p < .001$ two-tails; Experiment 2b, $p < .002$ two-tails; and Experiment 3, $p < .001$ two-tails. This analysis supports the claim that disruption of configural information has been effective in reducing overall recognition performance. Why should this be so?

One of the remarkable things about the often-made claim that the inversion effect in faces is due to the disruption of our ability to process configural information for inverted faces, is that it is exactly this type of information that might be expected to survive inversion. Inversion does not alter the spatial relationships between features at all, nor does it alter any variation about some configurational average (2^{nd} order information) unless we assume that its computation is tied to some template that has a fixed orientation. So, it may well be that the advantage we see for normal faces relative to scrambled ones in my experiment genuinely reflects the benefit of either expertise for, or better processing of, configural information in a face, a benefit that manifests equally for both upright and inverted faces because it is not tied to any particular orientation, but depends only on the spatial relationships within a face. This still leaves open the question of whether there are any effects of configural information that are orientation specific, all that can be said at this juncture is that the experiments reported so far in this thesis do not provide us with any evidence for this type of effect.

However if we go back to the results obtained in Chapter 2 of this thesis, we could say that Thatcherising the faces, leaving some configural information unaltered, did not entirely eliminate the FIE, even though there are three inverted isolable features in a Thatcherised face. So there are reasons for suspecting that configural information might have a role to play in the face inversion effect. The experiments I am about to report in this chapter sought to investigate the contribution that first-order and second order configural information may have in determining the FIE.

4.2 EXPERIMENT 5; Disrupting second-order relational information

4.2.1 Method

4.2.1.1 Materials

In this experiment I used 128 images of male faces because it was then easier to include the ears in the manipulation as well. The faces were standardised in grey scale format and cropped around the hairline using Adobe Photoshop. A programme called Gimp 2.6 was used to manipulate the 128 stimuli. Examples of the stimuli used are given in Figure 4.1. The experiment was run using Superlab Version 4.0.7b installed on an e-Mac computer.

I used a set of normal faces and a set of manipulated faces that I named No-Second info faces. In regard to these latter stimuli, I manipulated them so as to disrupt all the second-order relations without affecting first-order configurations or individual feature orientation. I selected and swapped the eyes first (this was a linear translation of the right eye to the left and vice-versa followed by smoothing), then flipped (reflected) the nose about its midline. I also swapped and flipped the ears. For the mouth, I flipped it, smoothed, and then flipped it back and smoothed again. This because if I had left the mouth in the flipped state the second-order relations between the nose and mouth would have been just as normal. By flipping and smoothing and then flipping back I made sure that each feature had been manipulated and, at the same time that all the second-order properties of a normal face were now disrupted, because a different transformation had been applied to each of the isolable features in that face. Each transformation was followed by smoothing, in order to avoid obvious contours that were the product of these manipulations.

For my set of normal faces I thought that I should match them in terms of manipulations with the set of No-Second info. faces, but without affecting first and second order relational information. Thus, I selected the two eyes, swapped them and then flipped them. The nose was flipped about its midline as was the mouth. Finally the ears were swapped and flipped. As a result of this the configural information among these features was unaltered, however, they were matched in terms of manipulations done to the set of No Second info. Faces, and were now, to some extent, "mirror-images" of the original face. Thus I named this set of normal faces “Mirrored” because the idea behind it was to swap the right half with the left of the face and then flip the features to maintain the configural information but require smoothing as for the experimental face set.

For both sets of stimuli the smoothing was designed to exclude any effect of luminosity or local features or blending. The idea here was to have the facial features arranged on a standard grey background. (see Figure 4.1). The final result was that there were two sets of stimuli that definitely were faces, with the No Second info. faces looking somewhat "strange" compared to the Mirrored ones.

Mirrored Upright **Mirrored Inverted** **No-Second info. Upright** **No-Second info. Inverted**

Figure.4.1 Examples of facial stimuli showing the four different conditions for Experiment 5. The dimensions of the stimuli were 7.95cm x 6.28cm. The stimuli were presented at a resolution of 1920 x 1080.

4.2.1.2 Participants

The participants were 32 psychology undergraduates at the University of Exeter. The study was counterbalanced by splitting the participants into 8 groups. Each participant group was shown the same 128 faces, but each group saw each face in a different condition.

4.2.1.3 Procedure

This was exactly the same as that used in all the face experiments reported in this thesis. In the counterbalancing the Mirrored and No-Second info.faces replaced the stimuli used in the previous experiments.

4.2.2 Results

In all the experiments reported in this chapter the analysis of the response latencies for the set of normal faces show that speed effects that parallel those on accuracy, (which was my primary measure), thus faster performance in recognising upright normal faces compared to that for inverted. For the manipulated faces the response latencies in the upright and inverted conditions were very similar. All the statistical tests in this chapter are two-tailed with an alpha of .05. I give the relevant F ratios and MSE, or the t value and the standard error for the effect tested. Simple effects analyses are uncorrected for multiple comparisons.

For completeness, the mean latencies for each condition in this experiment were (in msec): Mirrored Upright = 2148.12, Mirrored Inverted = 2199.04, No-Second info. Upright = 2159.92, No-Second info. Inverted = 2202.60. The data from all 32 participants were used in a signal detection analysis, where a d’ of 0 indicates chance level performance. ANOVA revealed there was no significant effect of Face Type, *F*(1, 31) =0.695, MSE = 0.211, p = .411, instead there was a significant effect of Orientation, *F*(1, 31) = 14.711, MSE = 0.455, p = .001, but no significant interaction between Face Type and Orientation F(1,31)=0.171, MSE = 0.240, p = .682 (see Figure 4.2). Simple effect analyses indicated that there was a strong inversion effect for mirrored faces, *t*(31) = 3.167 , SE = 0.155, p = .003, and a strong inversion effect for the No-Second info. set of faces as well, *t*(31) = 3.041 , SE = 0.138, p = .004.

Finally the Bias estimates for each of the four stimulus' conditions are: Normal Inverted, β= 0.952; Normal Upright, β= 1.424; No-Second info. Inverted faces, β= 1.121; No-Second info. Upright faces, β= 1.646.

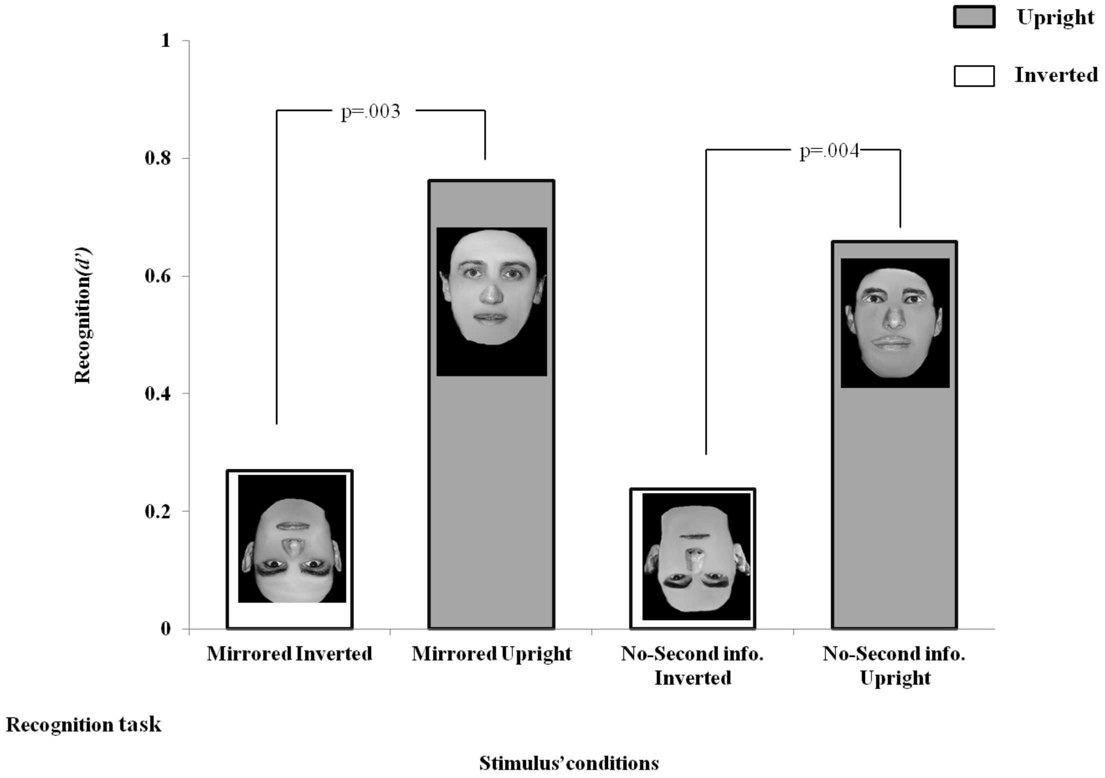


Figure.4.2 The X axis represents the four different stimulus conditions and the Y axis gives the mean d' for each of the four facial conditions in the old/new recognition phase of Experiment 5.

4.2.3 Discussion

The results from Experiment 5 show that my manipulations, which were intended to disrupt the second-order relational information of my faces, did not affect the size of the FIE. In fact the FIE for the of No-Second info. faces was as strong as the one for Mirrored (normal second order information) faces. A potential issue in this experiment is the fact that even if all the second order relations were disrupted however, No-Second info. faces still perceptually look very similar to controls (Mirrored), though I would argue that there is a clear difference between the two stimulus sets. Nevertheless, it could be argued that the manipulation used in this experiment was not severe enough to have a detectable effect. In the next experiment I tried to address these issues by using a set of normal faces (smoothed to control for any effect of local information and luminosity) and a set of what I call New Thatcherised faces which offered a more drastic manipulation of both the second-order properties and single feature orientation information but still left the first-order configuration of the faces as normal.

4.3 EXPERIMENT 6: New Thatcherised faces

4.3.1 Method

4.3.1.1 Materials

The study used 128 images taken from a different set of faces to that used in Experiment 5. The faces were standardised to have a grey scale colour on a black background using Adobe Photoshop. Only male faces were used. This was to enable the hair to be cropped on each image without cropping the ears (because males tend to have shorter hair with the ears visible, whereas females often have longer hair covering the ears). The faces were again manipulated using Gimp 2.6. This time I produced a set of normal faces and a set of what I will call New Thatcherised faces. The original manipulation, by Thompson (1988), involved rotating the mouth and each of the eyes (individually) by 180 degrees. And in Chapter 2 of this thesis I showed that the inversion effect for Thatcherised faces, even if somewhat smaller than for normal faces, is still significant. Thus, in Experiment 6 I manipulated my stimuli in a similar way. I rotated (by 180 degrees) one eye, one ear, and either the nose or mouth of sets of normal faces. The features rotated were counterbalanced so that I created 4 different sets of New Thatcherised faces each represented by a prototype. Exemplars drawn from the same category shared the same orientation and location of the features with the category prototype. Thus, this time, the second-order properties in a New Thatcherised face were visibly disrupted, particularly so given that I selected each eye with its eyebrow. This manipulation approximately balances the number of features that are upright in a face whether the face itself is inverted or not, thus controlling for the effect of individual features on inversion to some extent. If the second-order relations also play a significant role in the inversion effect, then this time the FIE should be strongly affected, perhaps even eliminated, because I would expect similar performance for New Thatcherised faces in both upright and inverted orientations as each possess roughly equal second order information, which in any case should be severely disrupted. I also cropped at the neck of each face to eliminate another source of information as to the orientation of the face. Both normal and New Thatcherised faces were smoothed as was done for the stimuli used in Experiment 5. Any given face stimulus was presented in four different conditions counterbalanced across the 8 participant groups i.e. normal upright, normal inverted, New Thatcherised upright and New Thatcherised inverted. Examples of the stimuli used are given in Figure 4.3. The experiment was run using Superlab Version 4.0.7b installed on an iMac computer.

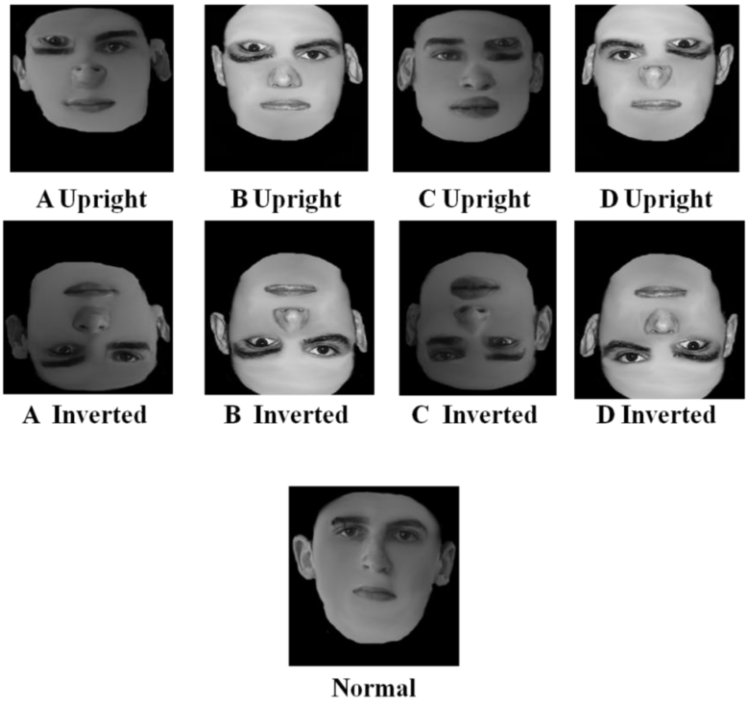


Figure.4.3 Examples of stimuli used in Experiment 6 showing the four category prototypes and an example of the normal faces used. The dimensions of the stimuli were 5.63cm x 7.84cm. The stimuli were presented at a resolution of 1280 x 960 .

4.3.1.2 Participants

24 psychology undergraduates at the University of Exeter took part in the experiment. The study was counterbalanced, as in Experiment 5, by splitting the participants into 8 groups.

4.3.1.3 Procedure

The experimental procedure used was exactly the same as before, just this time the 4 sets of New Thatcherised faces were counterbalanced across the participant groups.

4.3.2 Results

The mean latencies for each stimulus' condition used in this experiment (in msec) were: Normal Upright = 2544.37, Normal Inverted = 2605.97, New Thatcherised Upright = 2788.16, New Thatcherised Inverted = 2803.82. The data from all 24 participants were used in the signal detection d' analysis. ANOVA revealed there was not a significant main effect of Face Type, *F*(1, 23) = 1.062, MSE = 0.437 , p =.313, instead there was a significant main effect of orientation, *F*(1, 23) = 20.580, MSE = 0.222, p < .001, and a significant interaction between face type and orientation, *F*(1, 23) = 7.280, MSE = 0.044, p = .013 (see Fig.4.4). Thus, simple effect analyses were conducted showing that there was a strong inversion effect for Normal faces, *t*(23) = 4.232 , SE = 0.170, p < .001 , but no significant inversion effect for New Thatcherised faces *t*(23) = 1.424 , SE = 0.107, p =.16. Performance in recognizing Normal Upright faces was significantly better than recognition for Upright New Thatcherised ones *t*(23) = 2.866, SE = 0147., p =.008 (see Figure 4.4). Additional analyses were done to test performance against chance for each condition. Thus, Inverted Normal faces, *t*(31) = 1.229, SE = 0.128, p = .23; Upright Normal faces, *t*(31) = 8.571, SE = 0.102, p < .001 ; New Thatcherised Inverted faces *t*(31) = 2.148, SE = 0.140, p = .042, and New Thatcherised Upright faces *t*(31) = 4.860, SE = 0.093, p < .001.

Finally the Bias estimates for each of the four stimulus' conditions are: Normal Inverted, β= 1.136; Normal Upright, β= 1.388; New Thatcherised Inverted faces, β= 1.136; New Thatcherised Upright faces, β= 1.243.

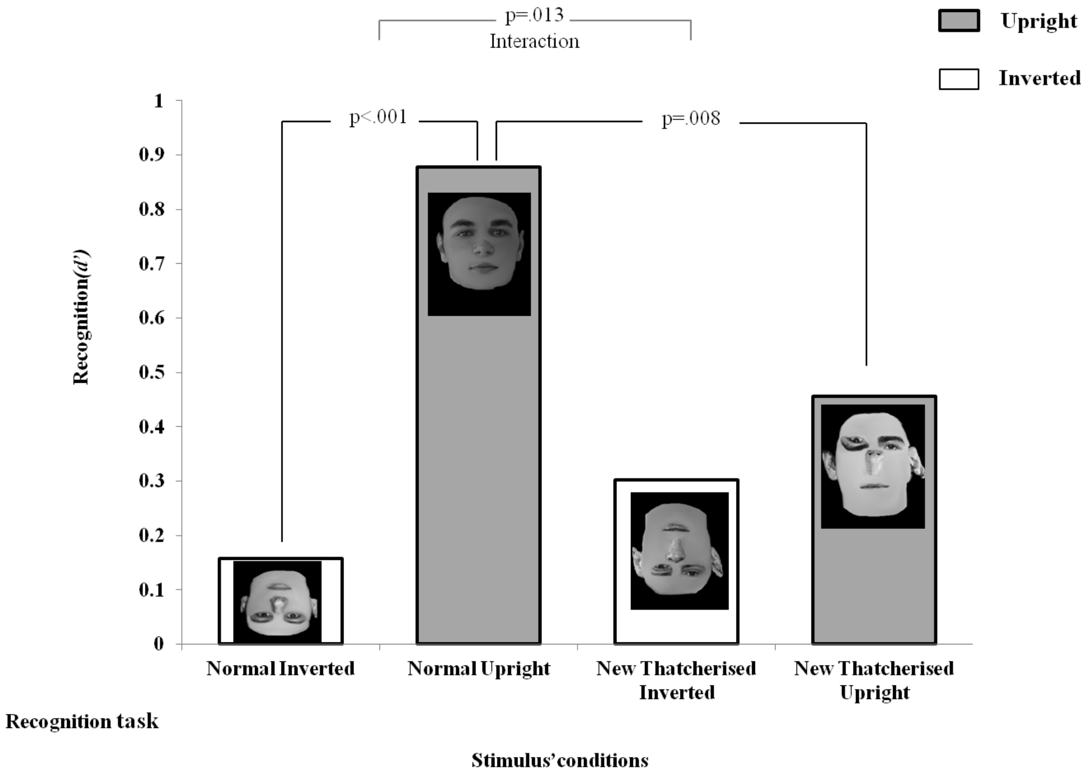


Figure.4.4 The X axis represents the four different stimulus conditions and the Y axis gives the mean d' for each of the four facial conditions in the old/new recognition phase of Experiment 6.

4.3.3 Discussion

Experiment 6 shows a strong FIE for the set of normal (but smoothed) faces and significantly better performance in recognising upright normal faces compared to New Thatcherised faces in an upright orientation. The main finding in this Experiment 6 is that the FIE for sets of New Thatcherised faces is not significant, however, it could be claimed that it has not entirely disappeared. I might say that the disruption of the second-order relational information in a more visible way (by Thatcherising the stimuli) significantly reduces the FIE compared to normal stimuli, but the results from earlier chapters suggest that the orientation of individual features is a more likely factor in bringing about these results. If we take into consideration the performance on both sets of inverted faces, we can clearly see numerically better (even if not significant) performance in recognising inverted New Thatcherised compared to normal inverted faces. This result can be easily explained by the fact that normal inverted faces have all the single feature orientation information disrupted (all the 6 main features are presented upside down) whereas New Thatcherised inverted faces still benefit from 50% of the features presented the right way up. The difference in performance on upright faces from the two sets can be explained in a similar fashion. The one difficulty with this analysis, which relies only on the orientation of isolated features, is that there is still a numerical inversion effect for the New Thatcherised faces, one that, if we allowed a 1-tail test would be marginally significant. There is something of a contrast between these results, however, and those obtained with scrambled faces, where the configural information must be completely disrupted, yet the inversion effect is not much affected. Thus in the next experiment I made a direct comparison between these two versions of the inversion effect.

4.4 EXPERIMENT 7; Scrambled faces versus New Thatcherised faces

4.4.1Method

4.4.1.3 Materials

In Experiment 7 I used the sets of scrambled faces previously reported in Chapter 3, and the sets of New Thatcherised faces used in Experiment 6. The four categories of scrambled and New Thatcherised faces were counterbalanced across the eight participant groups. The purpose of this experiment was to compare the FIE obtained based solely on the single feature orientation information with that obtained with the New Thatcherised faces, and to test the hypothesis that by leaving only the first-order relational information unaltered it is possible to obtain a significant FIE (i.e. to investigate the trend for an FIE with the New Thatcherised faces in Experiment 6).

4.4.1.2Participants

32 psychology undergraduates at the University of Exeter took part in the experiment. The study was counterbalanced, as in Experiments 5 and 6, by splitting the participants into 8 groups.

4.4.1.3Procedure

The experimental procedure used was exactly the same as before. The 4 sets of scrambled faces and 4 sets of New Thatcherised faces were counterbalanced across the 8 participant groups.

4.4.2 Results

The mean latencies for each stimulus' condition were: Scrambled Upright = 2474.67, Scrambled Inverted = 2591.90, New Thatcherised Upright = 2539.76, New Thatcherised Inverted = 2607.87. The data from all 32 participants were used in the signal detection d' analysis. ANOVA revealed there was a significant main effect of Face Type, *F*(1, 31) = 7.618, MSE = 0.260, p = .012 . Also there was a significant main effect of orientation, *F*(1, 31) = 9.563, MSE = 0.271 , p = .004 , however there was no significant interaction between face type and orientation, *F*(1, 31) = 0.104, MSE = 0.030, p = .749. Planned comparisons were conducted showing that there was a strong inversion effect for scrambled faces, *t*(31) = 2.562, SE = 0.122, p = .015, and a clear trend towards significance for New Thatcherised faces *t*(31) = 1.953, SE = 0.132, p = .06. Performance in recognizing New Thatcherised Upright faces was not significantly better (despite the clear numerical trend) than recognition for Upright Scrambled ones *t*(31) = 1.644, SE = 0.129, p = .11, however there was a significant difference in the recognition of New Thatcherised Inverted faces (which were better) compared to Inverted Scrambled faces, *t*(31) = 2.225, SE = 0.121, p .033 (see Figure 4.5). Additional analyses were done to test performance against chance for each condition. Thus, Inverted Scrambled faces, *t*(31) = 0.232, SE = 0.092, p = .817; Upright Scrambled faces, *t*(31) = 3.989, SE = 0.083, p < .001 ; New Thatcherised Inverted faces *t*(31) = 3.186, SE = 0.091, p = .003, and New Thatcherised Upright faces *t*(31) = 5.162 , SE = 0.106, p < .001.

Finally the Bias estimates for each of the four stimulus' conditions are: Scrambled Inverted, β= 1.026; Scrambled Upright, β= 1.054; New Thatcherised Inverted faces, β= 0.997; New Thatcherised Upright faces, β= 1.254.

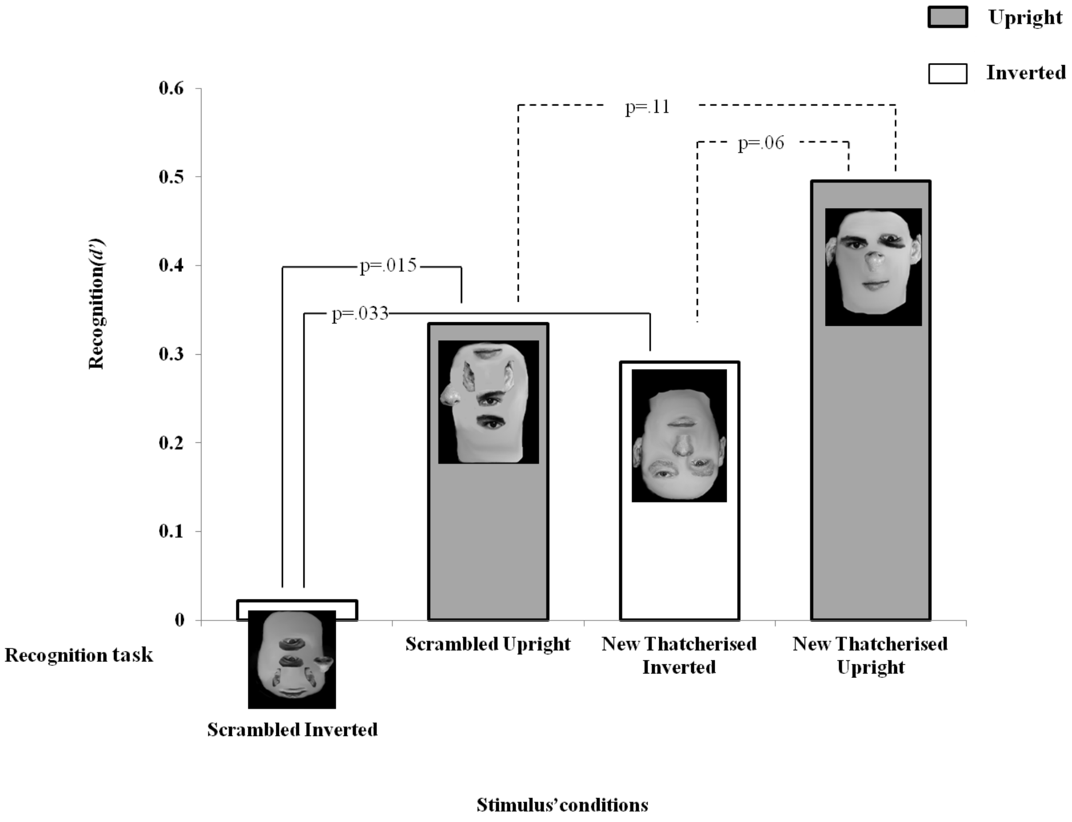


Figure.4.5 The X axis represents the four different stimulus conditions and the Y axis gives the mean d' for each of the four facial conditions in the old/new recognition phase of Experiment 7. The dashed lines indicate trends for the sets of stimuli in comparison.

4.4.3 Discussion

Firstly, the results from this Experiment 7 confirmed again a very robust finding in this thesis, which is that the full disruption of configural information which leaves the single feature orientations unaltered leads to a strongly significant inversion effect for sets of scrambled faces. Secondly, I find a near significant result for the inversion effect for New Thatcherised faces. It seemed very clear to me at this point that not only the single feature orientation, but also the first-order relational information may have a role in the FIE. A last comment concerns the performance on the two sets of stimuli at the upright orientation. First-order relations seem to confer a greater benefit in recognising the face compared to that due simply to single feature orientation information. Finally, the results for the inverted stimuli confirmed the influence of the amount of single feature orientation information possessed by the two sets of inverted stimuli. If six features are inverted, performance is worse than if only three are. The last experiment in this chapter aimed to: **i)** investigate if the trend for an inversion effect for the New Thatcherised faces can reach conventional levels of significance; **ii)** confirm the elimination of the FIE with 50% Feature-Inverted and Scrambled faces, supporting the results reported in Chapter 3 of this thesis; **iii)** investigate a potential orientation by face type interaction effect for New Thatcherised faces compared to 50% Feature-Inverted and Scrambled faces. The idea was see if it is possible to obtain the FIE when only the first-order relations are unaltered.

4.5 EXPERIMENT 8: New Thatcherised vs.50% Feature-Inverted and Scrambled faces

4.5.1 Method

4.5.1.1 Materials

Experiment 12 used the four categories of 50% Feature-Inverted and Scrambled faces previously used in Chapter 3, and the sets of New Thatcherised faces used in Experiments 6 and 7 in this chapter.

4.5.1.2 Participants

32 psychology undergraduates at the University of Exeter took part in the experiment. The study was counterbalanced, as in Experiment 5, 6 and 7, by splitting the participants into 8 groups.

4.5.1.3 Procedure

These were exactly the same as that used in the other experiments reported here.

4.5.2 Results

The mean latencies for the four stimulus' conditions were: 50% Feature-Inverted and Scrambled faces Upright = 2645.07, 50% Feature-Inverted and Scrambled faces Inverted = 2700.67, New Thatcherised Upright = 2351.17, New Thatcherised Inverted = 2424.42. The data from all 32 participants were used in the signal detection d' analysis. ANOVA revealed there was a significant main effect of Face Type, *F*(1, 31) = 4.090, MSE = 0.313 , p=.049. Analysis of main effect of orientation showed, *F*(1, 31) = 3.228, MSE = 0.385, p =.07. Finally, there was a significant interaction between face type and orientation, *F*(1, 31) = 4.619, MSE = 0.035, p = .047. Thus, simple effect analyses were conducted, showing that there was an inversion effect for New Thatcherised faces, *t*(31) = 3.150, SE = 0.123, p = .003, but there was no effect of inversion for 50% Feature-Inverted and Scrambled faces *t*(31) = 0.102, SE = 0.154, p = .91. Performance in recognizing New Thatcherised Upright faces was significantly better than recognition for Upright 50% Feature-Inverted and Scrambled faces *t*(31) = 3.098, SE = 0.126, p = .004, and also significantly better than recognition for Inverted 50% Feature-Inverted and Scrambled faces *t*(31) = 2.242, SE = 0.167, p = .032. Additional analyses show that all conditions were recognised significantly above chance level, Inverted 50% Feature-Inverted and Scrambled faces, *t*(31) = 2.165, SE = 0.119, p = .038; Upright 50% Feature-Inverted and Scrambled faces, *t*(31) = 2.317, SE = 0.105, p = .027 ; New Thatcherised inverted faces *t*(31) = 2.723, SE = 0.092, p = .010, and New Thatcherised Upright faces *t*(31) = 6.929, SE = 0.091, p < .001.

Finally the Bias estimates for each of the four stimulus' conditions are: 50% Feature-Inverted and Scrambled faces Inverted, β= 1.368; 50% Feature-Inverted and Scrambled faces Upright, β= 1.164; New Thatcherised Inverted faces, β= 1.142; New Thatcherised Upright faces, β= 1.114.

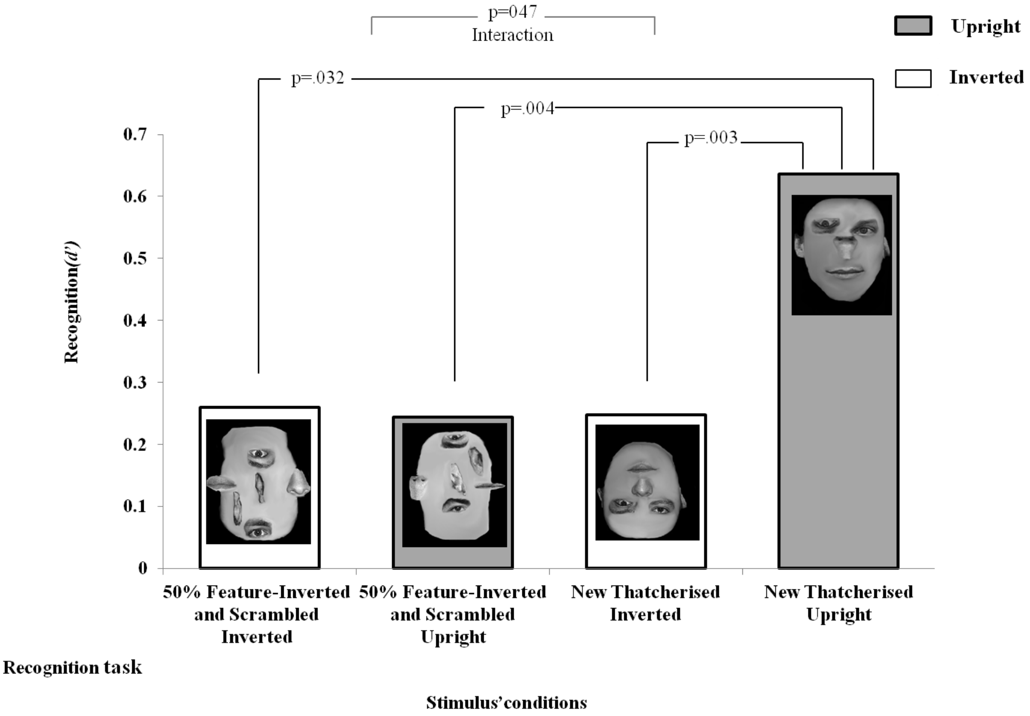


Figure.4.6 The X axis represents the four different stimulus conditions and the Y axis gives the mean d' for the old/new recognition phase of Experiment 8.

4.5.3 Discussion

The results of Experiment 8 essentially confirmed my predictions based on the results of earlier experiments. Thus, 50% Feature-Inverted and Scrambled faces abolished the FIE, whilst keeping recognition performance above chance levels. The New Thatcherised faces produced this time a strongly significant inversion effect, and the size of this effect was significantly greater than that for 50% Feature-Inverted and Scrambled faces. A final consideration regards the fact that three out of the four stimulus conditions presented in Experiment 8 show a very similar, almost equal performance level. These three conditions are matched in terms of the number of facial features presented in upright (50% of the features) and in inverted orientations (50% as well). Two of the conditions, those involving 50% Feature-Inverted and Scrambled faces, have the first and second order relations disrupted by my manipulations, whereas the New Thatcherised inverted faces still have first-order relations which have not been manipulated. Thus, this seems to suggest that inversion prevents the use of the first-order relational information. The advantage that participants have in recognizing New Thatcherised faces in an upright orientation makes a strong case for the first order configural information driving the inversion effect with these stimuli, by only being effective when the face is in its normal orientation.

4.6 GENERAL DISCUSSION

In the 4 experiments reported in this chapter 4 have investigated whether configural information does or does not affect the FIE. Experiment 5 suggested that if the second-order relational information is disrupted by keeping the configuration of the face (the first-order relations) unaltered, the FIE is still present. In fact, the FIE obtained in this condition was as large as that obtained with a set of normal faces. Experiment 6 brought more support for the claim that second-order information does not affect the FIE, in that even as drastic a manipulation as Thatcherising the faces did not entirely eliminate the effect of inversion. This trend for a significant inversion effect for the New Thatcherised faces was also found in Experiment 7, and was highly significant in Experiment 8. The results of these studies confirm that if I disrupt the second order configural information but leave the single feature orientations unaltered (scrambled faces) I can obtain an inversion effect with these stimuli. And finally, I was able to confirm that the inversion effect disappears only when both the first-order relations and single feature orientation information are manipulated. Given that the difference between the two sets of faces in Experiment 8 was whether they were scrambled or not, the significant interaction here allows me to quite conclusively answer the question "does configural information play a part in the FIE" by saying "yes". I would argue that the main finding of these experiments is that they provide clear evidence that it is possible to obtain an inversion effect when the first-order relations are the main factor in play. This raises the question of why would first-order relations be one of the things that help discriminations in the upright condition? If we think about first-order information, it is what is commonly shared across every facial exemplar, in some sense the average of the main spatial relationships between the features inside a face. A potential explanation for its influence on the FIE comes from studies supporting the “holistic” process account of face recognition. Hole et al., (1999) suggested there is more than one type of relational processing. Thus, they interpreted their results (that recognition of the top half of a composite face, constructed from top and bottom halves of different faces, is difficult when the face is upright, but not when it is inverted, even for image negatives) by suggesting that upright negative chimeric faces are sufficiently `face-like' to evoke holistic processing. On this view, holistic processing is elicited by anything that roughly conforms to the basic plan of a face, and it is holistic encoding that establishes that it is a face that is being perceived, as opposed to some other kind of object. Configural processing, by contrast, deals with the precise locations of the facial features relative to one another. According to Hole et al. it may be that inversion disrupts both holistic and configurational processing, whereas constructing a photographic negative of the facial image disrupts configural processing but leaves holistic processing intact. I suggest that perhaps it is first-order relations that elicit the face-like perception of the Thatcherised faces leading to the holistic analysis that benefits discrimination in the upright orientation. And perhaps it is the holistic process that explains the higher performance that participants showed for New Thatcherised faces compared to scrambled upright ones in Experiment 7, and led to the main effect of face type in that experiment. Thus, this suggests that in order to activate a holistic process for perception of face-like stimuli, the first-order relations provide important information, and single feature orientation on its own is not enough.

I finish by briefly considering the impact of these experiments on the case that can be made for expertise with the face category as being the basis for the inversion effect. Some of the strongest evidence for this type of explanation of the FIE comes from studies such as those of McLaren (1997) with chequerboards and Tanaka and Gauthier (1997) with Greebles that show that familiarisation with a new prototype-defined category can produce an inversion effect with stimuli drawn from that category. This inversion effect is then assumed to play some role in the FIE. The standard explanation for the inversion effect with these stimuli is that participants learn the configuration of features that defines the category (the prototype), and then become expert in detecting and using small deviations from this configuration (e.g. see McLaren's 1997 explanation based on McLaren, Kaye and Mackintosh, 1989). This may or may not be true, but my results suggest that it does not apply to faces, because the scrambling manipulation (Experiment 2a, 2b, 5 and 7) should completely disrupt any benefit due to familiarity with a configuration. Instead, the prediction that could be made based on the present results is that it is not the overall configuration of features that is the basis of the inversion effect in the studies with Greebles or chequerboards, but instead that the effect is based on familiarity with more local features. In some sense, the issue here is one of scale. Taking McLaren's prototype-defined chequerboards as an example, it may simply be that it is the spatial arrangement of the black and white squares at a relatively local level that is important, rather than the spatial relationships between more distal elements of the stimulus. Before any progress could be made in addressing this issue, however, I needed to confirm that McLaren's results held using my methodology. In the next chapter I aimed to test whether this was the case. Once participants are familiarised with a prototype-defined category, then using my study-test paradigm that is rather different to that of McLaren (1997), an effect of inversion on test would be expected to emerge for this set of stimuli. Additionally, I aimed to investigate to what extent this effect of inversion for a set of stimuli that participants had never seen before entering the experiment could be explained by the advantage that familiarity with the category brings to upright stimuli and/or the disadvantage that accrues to inverted stimuli.

Chapter 5: Perceptual learning and inversion effects: Recognition for a prototype-defined familiar category.

5.1 Introduction to the experiments

McLaren (1997) demonstrated that inversion effects similar to those found with faces could be obtained with artificial categories, if the participants in the experiment were first familiarised with those categories. He generated chequerboard exemplars that defined a category, by starting with a randomly generated base pattern (that had 50% black squares and 50% white), and then randomly changing some black squares to white and some white squares to black. Participants were trained first of all to categorise these stimuli, by requiring them to learn, by trial and error, to distinguish between exemplars derived from one base pattern or prototype (A), and exemplars from another randomly generated base pattern (B) that was constrained to share exactly 50% of it's squares with A. This ensured that participants paid careful attention to the exemplars they encountered, whilst in no way encouraging them to differentiate between members of the same category, only between members of different categories. Nevertheless, on a subsequent discrimination task that involved new exemplars from one of these familiar categories, participants demonstrated an enhanced ability to learn to distinguish between upright exemplars from the familiar category (relative to performance on exemplars drawn from a novel category) as predicted on the basis of the results obtained by McLaren, Leevers and Mackintosh (1994), who observed a similar effect. This advantage for upright exemplars was also accompanied by a disadvantage for the inverted exemplars (again relative to control stimuli taken from a novel category) in Experiment 1 of this paper, but this result was not replicated in Experiment 2 (though the numerical effect was in the same direction). The net consequence was demonstration of a strong inversion effect in both experiments for the exemplars drawn from the familiar category, in the absence of any such effect for exemplars drawn from a novel category derived from different base patterns but that otherwise possessed the same type of stimulus structure.

McLaren was able to explain the advantage for upright exemplars from the familiar category in terms of perceptual learning. Exposure to exemplars from the familiar category had led to enhanced within-category discriminability for exemplars from that category as in McLaren, Leevers and Mackintosh (1994). The mechanism for this effect was taken to be that proposed in McLaren, Kaye and Mackintosh (1989), namely the differential latent inhibition of common elements. Exposure to exemplars from a prototype-defined category will, on this theory, lead to profound latent inhibition of the prototypical elements for that category. Once this has occurred, when an exemplar drawn from that category is encountered, the elements that it shares with the prototype (and there will be many of them) will be latently inhibited, making them relatively less salient. The elements (what McClelland and Rumelhart, 1985, call micro-features) that are unique to that exemplar will not have been encountered very often, will not suffer greatly from latent inhibition, and so will be relatively salient. As it is these features or elements that allow one exemplar to be discriminated from another (it is the prototypical features that constitute the common elements that make exemplars confusable), discrimination between exemplars drawn from the familiar category will be enhanced.

This mechanism gives a good account of the advantage enjoyed by the upright exemplars, and it can explain the inversion effect by simply pointing out that this mechanism only applies to what has been experienced, and participants have not experienced inverted exemplars during the earlier familiarisation phase. It also predicts that if the category is not prototype-defined, but instead designed to a) allow categorisation on the basis of similarity, but b) in such a way that the differential latent inhibition of common elements mechanism cannot gain any traction, then no inversion effect should be obtained, and this was found to be the case in Experiment 1b. Thus, these results provided an account of inversion effects for familiar-prototype defined categories that promised to generalize to other cases such as faces, in line with the expertise-based explanation of the face inversion effect (FIE) pioneered by Diamond and Carey (1986).

As matters stand, however, there are some obstacles in integrating this theory of perceptual learning and these results with my understanding of the FIE. The first is that none of McLaren's (1997) experiments used the standard old/new recognition memory paradigm that is typically used to demonstrate the face inversion effect. To make the connection between inversion effects in this artificial category and faces, I need to demonstrate that after exposure, an inversion effect can be obtained with chequerboards drawn from the familiar category in this standard paradigm. Another lacuna that needs to be addressed is whether or not the disadvantage observed for inverted exemplars taken from the familiar category is reliable. If it is, then this result would be of considerable significance. It would establish that the inversion effect had two components (rather than being solely due to an advantage for upright exemplars), something that could not easily be demonstrated by any other means, given the difficulty in establishing the appropriate control baseline for comparison with faces for example. In this chapter I aimed to replicate and extend these findings. Thus, the first step was to extend McLaren’s findings to the old/new recognition paradigm normally used in face recognition studies.

5.2 Experiment 9a

5.3.1 Method

*5.3.1.1*Materials

The stimuli were 16 x 16 chequerboards containing roughly half black and half white squares. Four prototypes were randomly generated with the constraint that they shared 50% of their squares with each of the other prototypes, and were 50% black squares and 50% white. Exemplars were generated from these prototypes by randomly changing 48 squares as described in Fig.5.1.

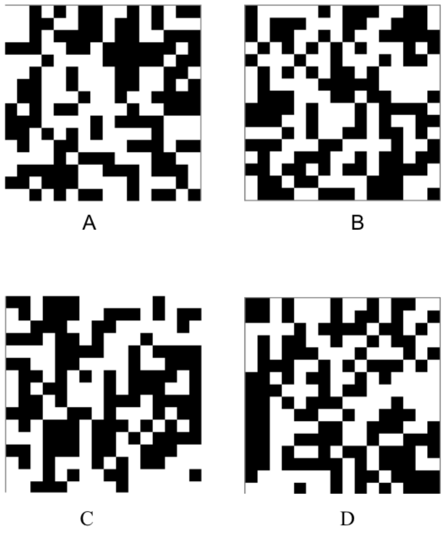


Figure.5.1. The prototypes for categories A, B, C and D. 48 of the squares were randomly changed to generate each exemplar, thus, on average, 24 squares would be expected to alter from black to white or white to black.

5.3.1.2 *Participants*

32 students at the University of Exeter took part in the experiment. The study was counterbalanced by splitting the participants into 8 groups.

5.3.1.3 *Procedure*

The study consisted of a ‘categorisation phase’, a ‘study phase’, and an old vs. new recognition ‘test phase’. In the categorisation phase, the subjects were instructed that once they pressed any key on the keyboard, a set of chequerboard stimuli would appear on the screen, one at a time, in a random order. Their task was to sort these stimuli into two categories by pressing one of the two keys (“x” or “.”), and they would get immediate feedback as to whether their response was correct or not. If they did not respond within 4 seconds, they would be timed out. The presentation of each stimulus was signalled by a warning cue (a fixation cross in the centre of the screen) presented for 1 sec. Each participant was shown 128 exemplars drawn from two different, prototype-defined categories, with 64 exemplars in each category. Subjects were encouraged to scan the whole of each chequerboard before categorizing it. In order to counterbalance our stimuli, we used 8 participant groups. The first 4 of those were presented, during the categorisation task, with 64 exemplars drawn from category A and 64 exemplars drawn from category B. The second 4 were presented with 64 exemplars drawn from each of the C and D categories. After the categorisation phase concluded, participants proceeded to the study phase. For each participant, the task was to look at a number of new exemplars from one of the two familiar categories seen in the categorisation task, plus exemplars from a novel category. Thus, for example, participant group 1 was presented with a set of stimuli that included 32 new exemplars (16 upright and 16 inverted) drawn from category A (familiar) and 32 exemplars (16 in each of the two orientations) drawn from category C (which was novel for them). To counterbalance this, participant group 5 was presented with 32 exemplars (16 upright and 16 inverted) drawn from category C (familiar) and 32 exemplars (16 in both orientations) drawn from category A, which was novel for that group. Thus, in the study phase each participant was shown 4 types of exemplars each containing 16 stimuli giving a total of 64 exemplars. These were presented one at a time and at random for 3 seconds each. The study conditions were thus: Familiar Inverted exemplars, Familiar Upright exemplars, Novel Inverted exemplars, and Novel Upright exemplars. Following the study phase, participants were given an old/new recognition task. This involved the 64 exemplars seen in the study phase (32 in an upright and 32 in an inverted orientation, as presented in the study phase), plus 64 new exemplars (32 in an upright and 32 in an inverted orientation) split across the same four conditions used in the study phase. As was the case for the face stimuli used in the experiments reported in earlier chapters, each exemplar had a unique identifying number, to make sure that an individual exemplar never appeared in more than one condition at a time during the experiment. To simplify their use in the experiment, the stimuli available were divided into sets of 16 giving 8 sets of stimuli, and each participant group was shown a different combination of the 8 sets. Each participant saw the stimuli corresponding to their participant group in a random order. Participants in the test phase were asked to press "." on the computer keyboard if they had seen the chequerboard before in the study phase, or "x" if they had not seen it, and had 4 seconds in which to do so. Data was collected on accuracy and latency for recognition performance across the test recognition phase.

5.3.2 Results

Following McLaren (1997), I expected an inversion effect (higher score for upright than for inverted) for the familiar category, no inversion effect for the novel category, and a significant difference between the effects of inversion for familiar and novel categories (i.e. an interaction). I also expected performance on upright exemplars from the familiar category to be better than on those drawn from the novel category, inverted exemplars drawn from a familiar category to be worse than their controls based on the 1997 data. In all the behavioural experiments reported in this chapter all the statistical tests are one-tailed with an alpha of .05. I give the relevant F ratios and MSE, or the t value and the standard error for the effect tested. Simple effects analyses are uncorrected for multiple comparisons.

In all the experiments reported in this chapter the analysis of the response latencies show similar performance for all the four stimulus' conditions. For completeness, the mean latencies for each condition in this experiment were (in msec): Familiar Upright = 2819.55; Familiar Inverted = 2816.73; Novel Upright = 2802.18; Novel Inverted = 2769.05. The data from all 32 participants were used in the signal detection *d'* analysis of the test phase where a *d'* of 0 indicates chance level performance. In the categorisation phase, the mean percentage correct was 67% (but note that this is a figure across the entire 128 trials of trial and error learning, and that the purpose of this phase is to expose participants to the stimuli, I am not especially concerned about categorisation accuracy). ANOVA did not show any effect of category type, *F*(1, 31) = 0.094, MSE = 0.258, p = .40, as any effect of orientation, *F*(1, 31) = 0.764, MSE = 0.076, p = .20. As predicted, there was a significant interaction between category type and orientation, *F*(1, 31) = 3.64, MSE = 0.170 p = .032. Figure 5.2 gives the results from the test phase. As expected, a significant difference in *d'* was found for the upright versus inverted familiar category exemplars, *t*(31) = 1.895, SE = 0.098, p = .033. No significant inversion effect was found for novel category exemplars, *t*(31) = 108, SE = 0.83, p = .288. To explore these results further the effect of category type on the recognition of upright exemplars was also analysed by means of planned comparisons on *d'* scores. Familiar upright exemplars were not recognised significantly better than unfamiliar upright exemplars, *t*(31) = 1.441, SE = 0.115, p =.08, though there was a clear trend in that direction. There was also a non-significant trend for familiar inverted exemplars to be worse than novel ones, *t*(31) = 0.963, SE = 0.116 , p = .171[1].

Bias estimates for each stimulus' conditions are: Familiar Upright, β= 1.072; Familiar Inverted, β= 0.996; Novel Upright, β= 1.016; Novel Inverted, β= 1.007.

I also performed a complementary Bayesian analysis on my data to provide additional information on the extent to which they provide evidence that either increases or decreases our confidence in the effects reported in the 1997 paper. The assumptions in running these analyses were that 1) the direction of the effect could be specified and would be that observed in the 1997 paper, and 2) that the d' differences were normally distributed with a standard deviation corresponding to the differences observed in the most comparable study from the 1997 paper. I felt that this was the right approach given that the stimuli were generated according to the same principles as used in 1997, but the procedures used in this experiment are rather different to those employed in McLaren (1997). Using these assumptions, I employed the Bayes factor calculator provided by Dienes (2011) with a half-normal distribution, and this gave a Bayes factor of 3.18 for the contrast between upright familiar and inverted familiar category exemplars, confirming that I can be confident of this inversion effect. The Bayes factor for the comparison between upright familiar and upright novel exemplars was 1.75, again indicating that we have more evidence (though I could not describe it as compelling at this point) for the 1997 effect. The Bayes factor contrasting novel inverted and familiar inverted exemplars (1.35) also suggests that I have some fairly weak additional evidence for this effect as well. I will continue to provide Bayes factors for these effects as I present the evidence from the studies reported in this chapter, in order to allow a judgment to be made on whether the 1997 results are confirmed by the current experiments.

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[1] The reason why I compare the upright chequerboards from familiar and novel categories, and inverted exemplars in the same way, is that, because of the counterbalancing, these sets of stimuli correspond to one another across participants, thus controlling for random variations in difficulty due to fluctuations in stimulus similarity. In other words, the set of Upright Familiar exemplars for one participant are the Upright Novel exemplars for another etc.

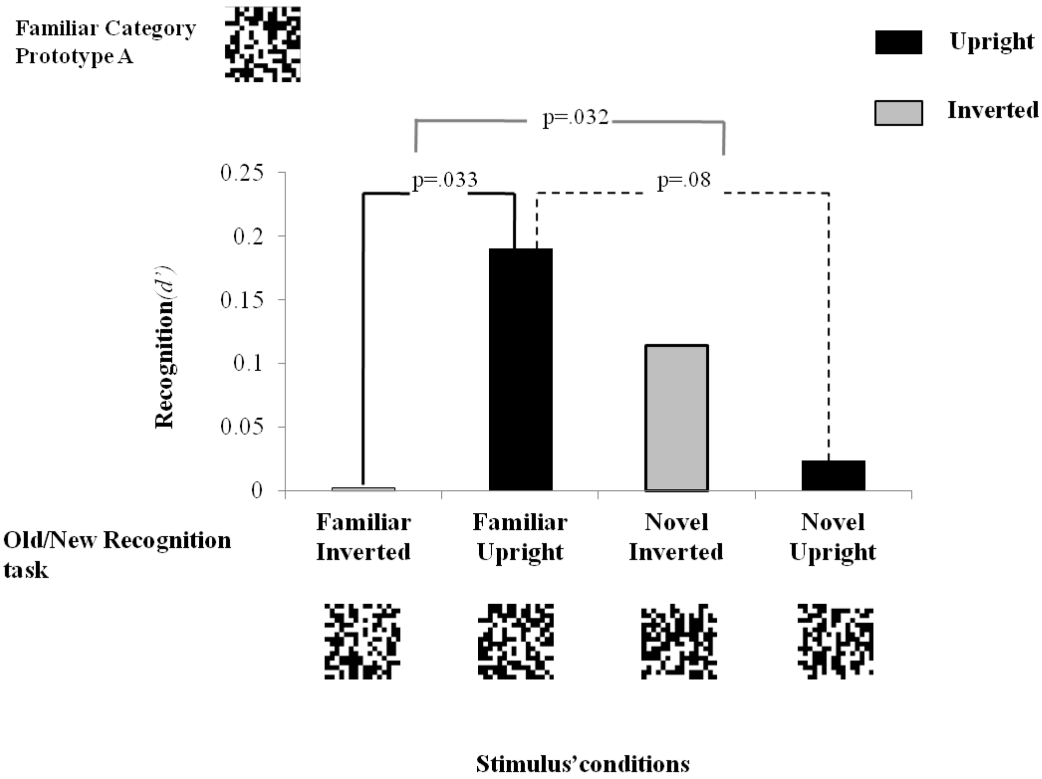


Figure.5.2. The X axis represents the four different stimulus conditions, and the Y axis gives the mean d' for each of the four facial conditions in the old/new recognition task of Experiment 9a.

4.3.3 Discussion

I have replicated the original McLaren (1997) effect with chequerboards, but this time using exactly the same paradigm as is normally used for face recognition studies. There is a significant inversion effect for the familiar chequerboards, but no inversion effect for novel chequerboards. Numerically, the results of this experiment are entirely in line with those of Experiment 1a in the 1997 paper, but the advantage for upright exemplars just fails to reach significance here, and the disadvantage is also unreliable. Nevertheless, these results do increase our confidence in the first of these effects, and does not undermine our confidence in the second (whilst not providing much additional support for it either). Before going on to consider these issues further, I first report a replication of Experiment 1b from the 1997 paper using the current recognition memory procedures, so that I am in a position to make as full a comparison as possible between our results now and the data reported then.

5.4 Experiment 9b

The same procedure was used again but this time there was an alteration in the method used to generate the stimuli. I used a variant of the algorithm for generating ‘shuffled’ stimuli outlined in McLaren (1997), as this produced stimuli that were as easy to classify as prototype-defined stimuli, but they did not average to the base pattern used to generate them, and so did not, as a class, possess a prototype themselves. In McLaren (1997) all 16 rows of a base pattern were randomly re-ordered to create each exemplar, which guaranteed that there could be no prototype for that category. The result was no reliable inversion effect, and the inversion effect obtained with prototype-defined categories was significantly larger than the inversion effect (such as it was) with shuffled categories, confirming that this effect depends on familiarity with a prototype-defined category. This time I used a restricted version of this algorithm in which exemplars were constructed by performing a random permutation of 3 horizontal lines of a base pattern (I used the prototypes from Experiment 9a) to give an exemplar of that category. I only shuffled three rows, to keep the number of squares that (on average) changed the same as in Experiment 9a, so that this experiment (9b) would be a better control for that one. The procedure was that two rows were identified at random and swapped, and then a new row was identified, and swapped with one of the previous two. The result was that, on average, half the squares in each of the three rows would be altered, making 24 in all. Thus, this experiment should be, in some sense, the control for Experiment 9a, though as will become apparent, the ease of classification produced by using these materials more nearly matched that of Experiment 10. Because this algorithm was based on the McLaren (1997) shuffling algorithm, I predicted no inversion effect for either familiar or novel category exemplars, and predicted an interaction with Experiment 9a similar to that in McLaren (1997).

5.4.1 *Participants*

32 students at the University of Exeter took part in the experiment. The study was counterbalanced, as in Experiment 9a, by splitting participants into 8 groups.

5.4.2 Results

The data from all 32 subjects was used for the analysis. In the categorisation phase, the mean percentage correct was 77%. Thus, as I predicted the stimuli were at least as easy to categorise as stimuli in Experiment 9a. However as Fig.5.3 suggests there was no significant difference in d-prime means for familiar category exemplars, or for novel category exemplars, confirming my predictions. Thus, ANOVA did not show any effect of category type, *F*(1, 31) = 0.005, MSE = 0.291, p = .944, as any effect of orientation, *F*(1, 31) = 0.013, MSE = 0.316, p = .911, as any effect of interaction between category type and orientation, *F*(1, 31) = 0.337, MSE = 0.260 p = .566 Figure 5.2. Bias estimates for each stimulus condition are: Familiar Upright, β = 1.087; Familiar Inverted, β = 1.108; Novel Upright, β = 0.965, Novel Inverted, β = 1.010. The crucial interaction, however, is not that within Experiment 9b, but emerges when we compare the results of Experiment 9b with those of Experiment 9a. In McLaren (1997) a similar comparison showed that the inversion effect, defined as the familiarity by orientation interaction, obtained with exemplars drawn from a prototype-defined category, was significantly greater than that obtained with exemplars drawn from a category that was not defined by a prototype. If we compute a 2x2x2 ANOVA, to find the Experiment by Familiarity by Orientation, interaction for Experiments 9a and 9b, we find a marginally significant result, *F*(1, 62) = 2.721, MSE = 0.215, p = .052, suggesting that this might be the case here as well. Thus, I have some supporting evidence enabling me to claim that the inversion effect depends on both the category being familiar and its being based on a prototype. Calculating the Bayes factor for this analysis based on the 1997 priors gives a Bayes factor of 2.50, also suggesting that there is good, but not conclusive evidence for this effect.

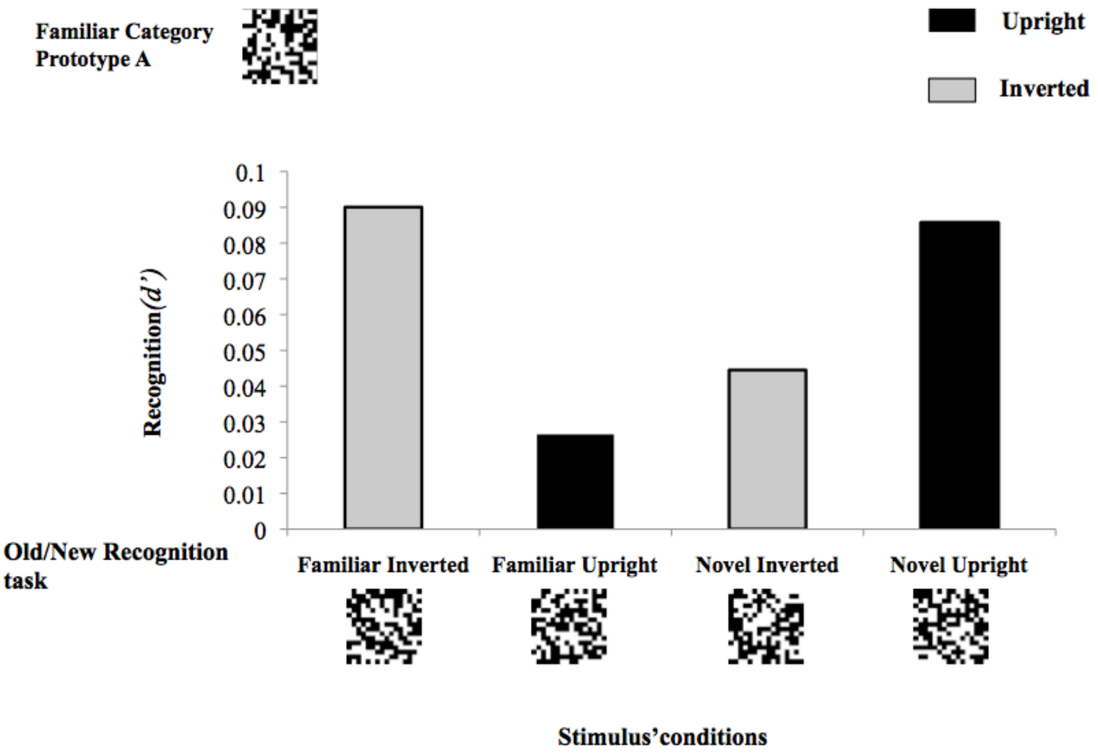


Figure.5.3. The x-axis shows the four different stimulus conditions, and the y-axis shows the d' scores for each of the four conditions in the test phase of Experiment 9b.

5.4.3 Discussion

Experiment 9b did not produce any of the effects observed in Experiment 9a, despite my controlling for the number of squares changed to produce the exemplars and ensuring that the categorisation task was at least as easy in 9b as it was in 9a. My argument is that this is because the different algorithm for generating exemplars produces a category with a different structure, one in which the influence of any prototype is considerably weaker. I defer a detailed discussion of how the theory of perceptual learning in McLaren, Kaye and Mackintosh (1989), that is further developed in McLaren and Mackintosh (2000, 2002), and McLaren, Forrest and McLaren (2012) can explain these effects until the General Discussion, but offer some thoughts here on just why the two algorithms lead to such different results.

Clearly this new version of the original shuffling algorithm now shifts the exemplars produced by it towards those obtained with the standard prototype-defined exemplar generation algorithm. This is because fewer squares are changed and the average of all these exemplars will now somewhat resemble the base pattern. But there are important differences between these algorithms and the exemplars they generate. These follow from the fact that the shuffling algorithm maintains the identity of rows – they move as a whole. Because of this, a column that has few black squares say, will tend to "wash out" the black squares in that column, whilst a column that has a preponderance of black squares will do the opposite, and tend to "obscure" any white squares in that column. The net effect of this is that the prototype extracted from averaging these exemplars will be rather blurred, and the most salient invariant information in the exemplars diagnostic of the category is their average column luminance rather than the identity of individual squares. Another consequence of the shuffling algorithm is that any individual square always has invariant left and right neighbours, meaning that a good part of its immediate context never changes. Contrast this with the random replacement that takes place in the case of exemplars generated so as to produce a prototype-defined category. There will be no tendency for any square's average luminance to be shifted in the direction of the preponderant square colour for that column, instead all squares will be affected equally, and so there will be no "overlay" of columnar structure on the prototype. And there will be no guarantee that the squares to either side of a given square do not change. I believe that these differences are crucial in producing the lack of any inversion effect in the shuffled stimuli, and will show why this is the case in the General Discussion of this chapter. For the moment I note that the outcome of this experiment is that it has allowed a near replication of the category type by familiarity by inversion interaction from McLaren (1997), which strongly suggests that the inversion effect is contingent on both familiarity with the category of stimuli concerned but also their possessing the correct categorical structure. Thus, it is not the case that an inversion effect can be obtained via familiarisation with any set of chequerboards that can be distinguished from some other set, there seems to be a requirement that the set be defined by a prototype for this procedure to work.

However, the inversion effect in Experiment 9a is not as substantial as I would like, and I speculate that this may be because participants found it too hard to recognize the chequerboards in this experiment. Because of this, performance on all the different types of chequerboard became too close to floor to make it easy to decide if inverted chequerboards from the familiar category were actually harder to recognize than inverted chequerboards from the novel category, i.e. whether the disadvantage for inverted chequerboards drawn from a familiar category reported in McLaren (1997) was real. Experiment 10 aimed to address this issue.

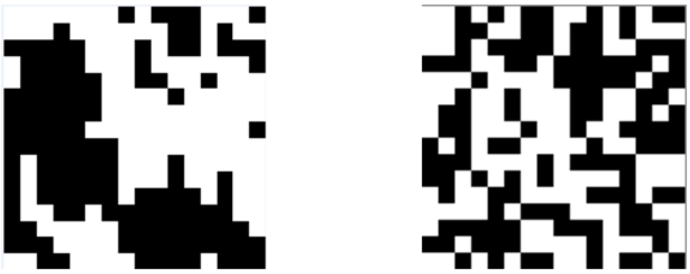
5.5 Experiment 10

Experiment 10 was a replication of Experiment 9a, but this time I tried to make the chequerboards “clumpier”, with the intention of making the stimuli easier to recognize (see Fig.5.4). I hoped to obtain a stronger inversion effect for familiar chequerboards than the one obtained in Experiment 9a.

5.5.1 Method

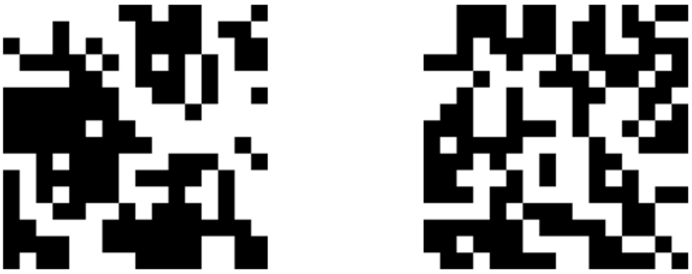
*5.5.1.1*Materials

In this experiment a randomly chosen 96 squares (up from the 48 used in Experiment 9a) were set at random to generate each exemplar from the base prototype, and the prototypes themselves had stronger differentiation into black and white areas (see Fig.5.4). This was accomplished by making the probability of a square being a particular colour depend on the colour of its neighbours, so that if they were predominantly black, then that square had a greater chance to be black, and vv. for white. The result was a set of prototype patterns that were still 50% black and 50% white, and still overlapped 50% with one another, but with the squares of a particular colour clumped together.



Prototype A
Experiment 10

Prototype A
Experiment 9a



Exemplar A65
Experiment 10

Exemplar A65
Experiment 9a

Figure.5.4.The prototypes and some exemplars for category A in Experiment 9a and for category A in Experiment 10.

*5.5.1.2*Participants

32 students at the University of Exeter took part in the experiment. The study was counterbalanced, as in Experiment 9a, by splitting participants into 8 groups.

*5.5.1.3*Procedure

This was exactly the same as that used in Experiment 9a.

5.5.2 Results

For completeness, the mean latencies for each condition in this experiment were (in msec): Familiar Upright = 2787.36; Familiar Inverted = 2803.51; Novel Upright = 2795.72; Novel Inverted = 2860.38.The data from all 32 subjects was used in the analysis. In the categorisation phase, the mean percentage correct was 77%, indicating that my manipulation of the stimuli had made them easier to classify compared to Experiment 9a (and identical, in terms of ease of classification, to Experiment 9b). Results from ANOVA once again did not show any effect of category type, *F*(1, 31) = 0.960, MSE = 0.135, p = .17, as any effect of orientation, *F*(1, 31) = 2.376, MSE = 0.192, p = .07. There was a significant interaction between category type and orientation, *F*(1, 31) = 4.13, MSE = 0.182, p =.025. Fig.5.5 gives the results for the mean d' score by stimulus type. Planned comparisons were used to examine whether or not there was a significant inversion effect for familiar category exemplars. A reliable difference in d' emerged for the upright versus the inverted familiar category exemplars, *t*(31) = 2.845, SE = 0.095, p = .004. No significant inversion effect was found for novel category exemplars, *t*(31) = 0.284, SE = 0.119, p = .389.To explore this further the effect of category type on the recognition of upright exemplars was also analysed. Familiar upright exemplars were not recognised significantly better than unfamiliar upright exemplars, *t*(31) = 0.977, SE = 0.091, p=.17, but novel inverted exemplars were recognised better than familiar inverted exemplars, *t*(31) = 2.030, SE = 0.106, p =.025.

Bias estimates for each stimulus' conditions are: Familiar Upright, β= 1.056; Familiar Inverted, β= 1.050; Novel Upright, β= 1.032; Novel Inverted, β= 0.987.

I also computed Bayes factors for these contrasts using priors based on Experiment 9a. The Bayes factor for the inversion effect in the familiar category was 20.88, indicating that I can have a great deal of confidence in this finding. For the novel category, the Bayes factor for the inversion effect was 0.25, indicating that the evidence is indifferent with respect to the null hypothesis of no effect. The interaction for these two effects has an associated Bayes factor of 4.47, suggesting that I can also be confident that the inversion effect in the familiar category is bigger than that in the novel category. The Bayes factor for the contrast between upright exemplars from the familiar and novel categories is 1.15, suggesting that I have no decisive evidence on this effect, but that for comparison of the inverted stimuli is 3.74, indicating that I am now in a position to be confident that performance in the recognition task on the inverted exemplars drawn from the novel category is superior to that on the inverted exemplars drawn from the familiar category.

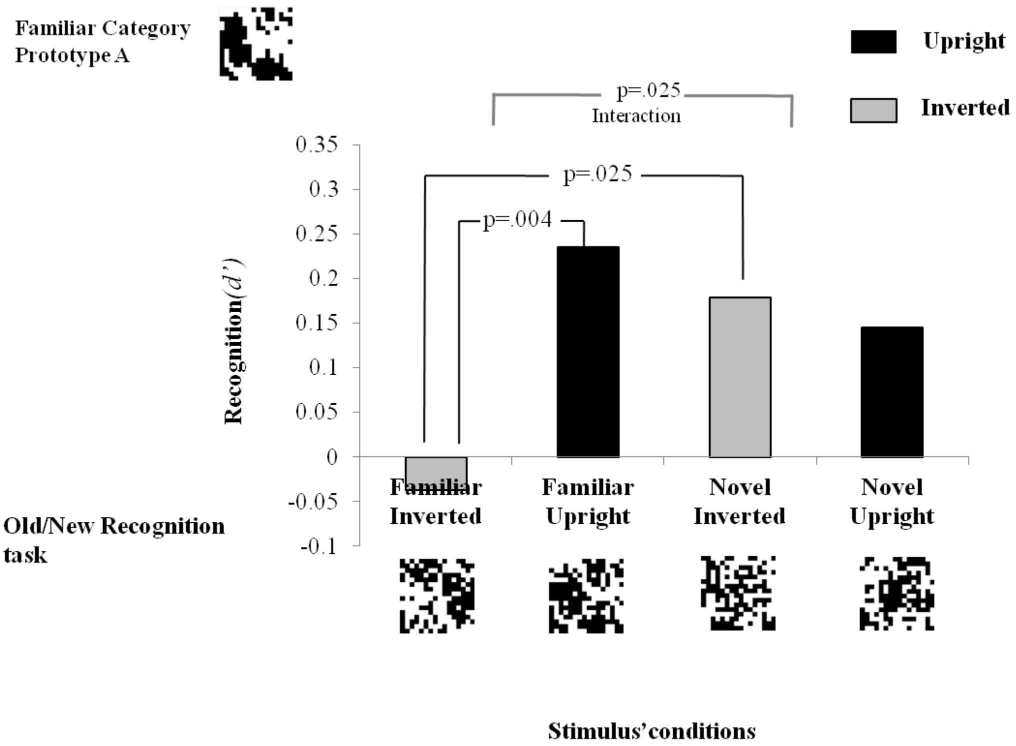


Figure.5.5. The X axis gives the four different stimulus' conditions, and the Y axis shows the mean d-prime scores for the old/new recognition phase in Experiment 10.

5.5.3 Discussion

Experiment 10 replicated and strengthened the findings obtained in Experiment 9a. I was able to increase the size of the inversion effect for chequerboards drawn from a familiar category by making them easier to recognize. Thus, my results confirm that an inversion effect can be induced by familiarizing participants with a prototype-defined category. I am also able to comment further on the basis for this effect. The trend for familiar upright exemplars to be better recognised than novel upright exemplars was unconvincing (though the effect was numerically in the same direction), but this time inverted familiar exemplars were significantly worse recognised than novel inverted exemplars. The basis of the inversion effect obtained with prototype-defined categories may well be, in part, due to some advantage for the upright exemplars from the familiar category. This was significant in McLaren's (1997) results, and though not independently significant in the two relevant studies reported so far, the combined Bayes factor for this effect is now over 2.Thus, the evidence on this point, whilst still not compelling, is in line with that in McLaren (1997). We can perform a similar analysis for the disadvantage accruing to inverted exemplars drawn from a familiar category. If we combine the two experiments reported here we get a Bayes factor of over 5, suggesting we can have real confidence in this effect. This strongly suggests that the effect observed by McLaren (1997) in one of his experiments was real. It also indicates that the inversion effect may be as much to do with a disadvantage for inverted familiar exemplars as it is to do with an advantage for upright familiar exemplars, matching the patterns of results described in Chapter 3 of this thesis using faces. Also if we look back at Yin’s (1969) study, and focus on his Experiment 1, he found that normal faces in an inverted orientation were more difficult to recognize than other inverted sets of stimuli. A major criticism that can be levelled at this finding is that the sets of stimuli used in Yin’s (1969) study i.e. for example pictures of houses or airplanes, did not match normal faces in terms of structure and the information contained in the stimuli. For example, the number of features and the complexity of their configurations varied widely across these stimuli. However, in the experiments reported in this chapter I have found a substantial disadvantage for inverted chequerboards taken from a familiar category, and this suggests that Yin's (1969) finding reflected some underlying reality despite the lack of control in his experiment.

5.6. Experiment 11

On the negative side, my conclusions from Experiments 9a, 9b and 10 depend in part on the cross-experiment comparison between Experiments 9a and 9b. The aim of Experiment 9a was to demonstrate that the inversion effect requires that the stimuli belong to categories defined by their relation to a common prototype (having common features) and will not occur for rather similar sets of stimuli that lack this property. However the main issue with this claim is that only a trend towards significance was found when I compared the inversion effect interactions from Experiments 9a and 9b. Thus, in the next experiment (Experiment 11) the logical step was to run Experiment 9a and 9b but this time by using the type of chequerboards used for Experiment 10. Finally, to make my conclusions secure, this time the two conditions were run together within the same Experiment 11.

5.6.1 Method

*5.6.1.1*Materials

For Experiment 11 the categories of chequerboards used in were the same as used in Experiment 10. Thus, I already had the four sets of exemplars generated from Category prototypes A, B, C and D. My next task was to construct matched shuffled exemplars. Recall that in Experiment 9b to change 24 squares (on average) I shuffled three rows. First two were selected and swapped (let’s call them 1 and 2), then a new row was selected (let’s call it 3) and 2 and 3 were swapped. This meant that a maximum of 48 squares could change, and on average 24 would. In what I will call the New Shuffled exemplars used in Experiment 11b on average 48 squares are changed - with a maximum of 96 possible. This was done by continuing the process I employed in Experiment 9b. Each time I selected another row, I changed, on average, another 8 squares, and so 6 rows were altered in total.

*5.6.1.2*Participants

32 students at the East China Normal University took part in the experiment.

5.6.1.3*Procedure*

The procedure within the different experiment conditions was exactly the same as in the previous experiments reported in this chapter. Thus, the subjects were presented with a categorisation task, followed by a study phase and finally there was an old/new recognition task. However this time 16 of the subjects performed with prototype defined chequerboards, and 16 subjects performed with shuffled chequerboards in alternation. Thus, each participant was matched in terms of the stimuli used (i.e. in the allocation of prototypes to conditions) - The only difference is in how the exemplars were generated from those prototypes.

5.6.2 Results

The data from all 32 subjects was used in the analysis divided by the two main experiments, 11*a* and 11*b*. The results from Experiment 11*a* show: In the categorisation phase, the mean percentage correct was 82%, confirming what was already showed in Experiment 10, thus my manipulation of the stimuli had made them easier to classify compared to Experiment 9a. Results from ANOVA once again did not show any effect of category type, *F*(1, 15) = 0.759, MSE = 0.655, p = .19, however a significant effect of orientation, *F*(1, 15) = 2.993, MSE = 0.271, p = .048. Finally there was a significant interaction between category type and orientation, *F*(1, 15) = 5.389, MSE = 0.430, p =.014. Fig.5.6 gives the results for the mean d' score by stimulus type. Planned comparisons were used to examine whether or not there was a significant inversion effect for familiar category exemplars. A reliable difference in d' emerged for the upright versus the inverted familiar category exemplars, *t*(15) = 3.381, SE = 0.146, p = .001. No significant inversion effect was found for novel category exemplars, *t*(15) = 0.659, SE = 0.192, p = .258.To explore this further the effect of category type on the recognition of upright exemplars was also analysed. Familiar upright exemplars in this experiment were not recognised significantly better than unfamiliar upright exemplars, *t*(15) = 0.737, SE = 0.226, p=.23, but novel inverted exemplars were recognised better than familiar inverted exemplars, *t*(15) = 2.295, SE = 0.198, p =.015.

Bias estimates for each stimulus' conditions in this Experiment 11a are: Familiar Upright, β= 0.983; Familiar Inverted, β= 1.079; Novel Upright, β= 1.233; Novel Inverted, β= 0.943.

The results from Experiment 11b show that in the categorisation phase, the mean percentage correct was 88%. Thus, these stimuli were at least as easy to categorise as the stimuli in Experiment 11a. However, as Fig.5.6 suggests, there was no significant difference in d-prime means for familiar category exemplars, or for novel category exemplars, confirming my predictions. Thus, ANOVA did not show any effect of category type, *F*(1, 15) = 0.637, MSE = 0.327, p = .433, as any effect of orientation, *F*(1, 15) = 0.007, MSE = 0.247, p = .933, as any effect of interaction between category type and orientation, *F*(1,

15) = 0.039, MSE = 0.202 p = .845. Bias estimates for each stimulus condition are: Familiar Upright, β = 1.087; Familiar Inverted, β = 1.108; Novel Upright, β = 0.965, Novel Inverted, β = 1.010. The 2x2x2 ANOVA gave an *F*(1, 30) = 3.253, MSE = 316, p = .039. supporting the claim that the inversion effect depends on both the category being familiar and its being based on a prototype. Calculating the Bayes factor for this analysis based on the Experiment 9a and 9b priors gives a Bayes factor = 6.11, suggesting that there is now very strong evidence for this effect. As for Experiment 10 here as well I also computed Bayes factors for these contrasts using priors based on Experiment 9a. The Bayes factor for the inversion effect in the familiar category was 55.38, indicating that in case as well I can have a great deal of confidence in this finding. For the novel category, the Bayes factor for the inversion effect was 1.12,indicating that the evidence is indifferent with respect to the null hypothesis of no effect. The interaction for these two effects has an associated Bayes factor of 6.92, suggesting that I can also be confident that the inversion effect in the familiar category is bigger than that in the novel category. The Bayes factor for the contrast between upright exemplars from the familiar and novel categories is 1.17, suggesting that I have no evidence on this effect, but that for comparison of the inverted stimuli is 3.90, confirming that performance in the recognition task on the inverted exemplars drawn from the novel category is superior to that on the inverted exemplars drawn from the familiar category.

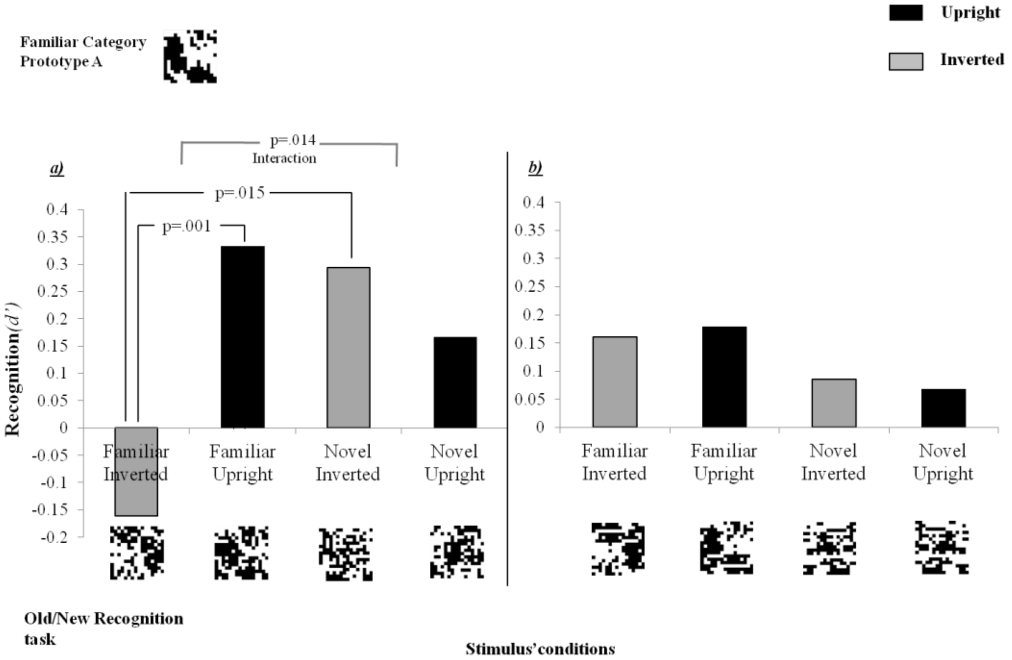


Figure.5.6. Panel *a)* represents the results obtained in Experiment 11*a*. Panel *b)* represents the results obtained in Experiment 11*b*. Thus in both panels the X axis gives the four different stimulus' conditions, and the Y axis shows the mean d-prime scores for the old/new recognition phase in the experiment.

Discussion

Experiment 11 has essentially confirmed my predictions. Thus, the results show that the inversion effect requires that the exemplars are drawn from a prototype-defined category. Experiment 11 supports the main findings in Experiments 9a and 9b. It also confirms that the sets of chequerboards used in Experiment 10 are easier to recognise and show stronger effects compared to the effect shown in Experiment 9a.

5.6Experiment 12

As I have already mentioned in this thesis, several studies on face recognition using ERPs have demonstrated a difference in the ERPs to faces and objects at between 150-200 ms in bilateral occipito-temporal regions (Bentin et al., 1996; Eimer, 2000; Rossion et al., 2000). Rossion et al., found that the N170 is both increased and delayed when faces were presented after inversion, but that this difference was not obtained for inverted classes of objects for which participants were not experts e.g., shoes. This effect of inversion on the N170 for faces is robust, and it has been obtained in several ERP studies (Rossion, Delvenne, et al., 1999; Rossion et al., 2000; Taylor, McCarthy, Saliba, & Degiovanni, 1999). The first evidence of an inversion effect on the N170 for a class of stimuli different from faces we are aware of comes from Rossion, Gauthier, Goffaux, Tarr and Crommelinck‘s (2002) study with “Greebles”. However there are two main issues that arise from their study. First of all, one could object that stimuli such as Greebles are still quite similar to faces in the way that they share a basic configuration of features which themselves vary, and they are mono-orientated stimuli. However, other studies have indicated that Greebles are not treated as face-like until after familiarisation (Tarr & Gauthier, 2000), so the effect is unlikely simply to be due to some transfer between faces and Greebles. Secondly, the effect of familiarity producing an inversion effect in Greebles was larger on the left than the right occipito-temporal side. In contrast, other studies had shown that most expertise-based effects recorded during fMRI were found on bilateral sites or only on the right (Gauthier et al., 2000). Similarly, several studies using fMRI have found greater activation for faces in the right-hemisphere “fusiform face area” (FFA), raising the question of whether the effect seen with Greebles is truly analogous to that in faces. In Experiment 12, I investigated the electrophysiological correlates of my behavioural results, by investigating whether I could find an N170 for the familiar chequerboards that was increased and delayed by inversion. I also noted any left-right localization for any such effect.

5.6.1 Method

*5.6.1.1*Materials

The categories of chequerboards used in this Experiment 12 were the same used in Experiment 10.

*5.6.1.2*Participants

32 students at the University of Exeter took part in the experiment.

5.6.1.3 *Procedure*

The experimental procedure was identical to the one used in Experiment 10. However, I doubled up the number of trials to allow for better signal averaging and to obtain a more reliable ERP. To make this possible, the experiment was split into two parts: each including a ‘categorisation task’ followed by a ‘study phase’ and an ‘old/new recognition task’. Straight after the first part, participants were presented with the second part in which another ‘categorisation task’ followed by a ‘study phase’ and ‘an old/new recognition task’ were shown. The categories of stimuli were counterbalanced across the two experimental parts in such a way that if a category was processed in the first part then that category was not presented again in the second part.

5.6.1.4 EEG Apparatus

This was exactly the same as in Experiment 1 of this thesis.

5.6.1.5 EEG Analysis

Here also the process was the same as the one used in Experiment 1 of this thesis.

5.6.2 Results

5.6.2.1 Behavioural results

The data from all 32 subjects was averaged across the two parts of the experiment and used in the analysis. In the categorisation phase, the mean percentage correct was 88%. Results from ANOVA did not show any effect of category type, *F*(1, 31) = 0.319, MSE = 0.117, p = .28, however a significant effect of orientation, *F*(1, 31) = 3.785, MSE = 0.132, p = .030. ANOVA results from the test phase showed a significant interaction between category type and orientation, *F*(1, 31) = 4.91, MSE = 0.101, p =.017. Planned comparisons were used to examine whether or not there was a significant inversion effect for familiar category exemplars. A reliable difference in d' emerged for the upright versus the inverted familiar category exemplars, *t*(31) = 2.988, SE = 0.083, p=.002. No significant inversion effect was found for novel category exemplars, *t*(31) = 0.003, SE = 0.087, p = .498. To explore this further, the effect of category type on the recognition of upright exemplars was also analysed. Familiar upright exemplars were not recognised significantly better than unfamiliar upright exemplars, *t*(31) = 1.179, SE = 0.076, p = .12, but there was a significant tendency for novel inverted exemplars to be better recognised than familiar inverted exemplars, *t*(31) = 1.803, SE = 0.088, p = .04.

Bias estimates for each stimulus’ conditions are: Familiar Upright, β= 1.053; Familiar Inverted, β= 1.040; Novel Upright, β= 1.091; Novel Inverted, β= 1.065.

A complementary Bayesian analysis using Experiment 10 to generate priors revealed that the Bayes factor for the effect of inversion on familiar chequerboards was 35.74, the effect of inversion on novel chequerboards had an associated Bayes factor of 0.50, and that the Bayes factor for the interaction was 5.97. The Bayes factor for the comparison between upright stimuli was 1.59, and that for inverted stimuli was 2.86. Thus, the overall Bayes factor (obtained by multiplying the individual Bayes factors from each experiment) for the comparison between familiar upright stimuli and novel upright stimuli is now 3.74 and hence we can be confident that the procedures produce an inversion effect that has a component attributable to an advantage for the familiar upright stimuli; and as the Bayes factor for the comparison between the inverted stimuli also comfortably exceeds 3 (it's actually 56.431), I can be confident that there is a component attributable to a disadvantage for familiar inverted stimuli. Fig.5.6 shows the results for the mean d' score by stimulus type, and the pattern is very similar to that obtained in Experiments 9a, 10 and 11a.

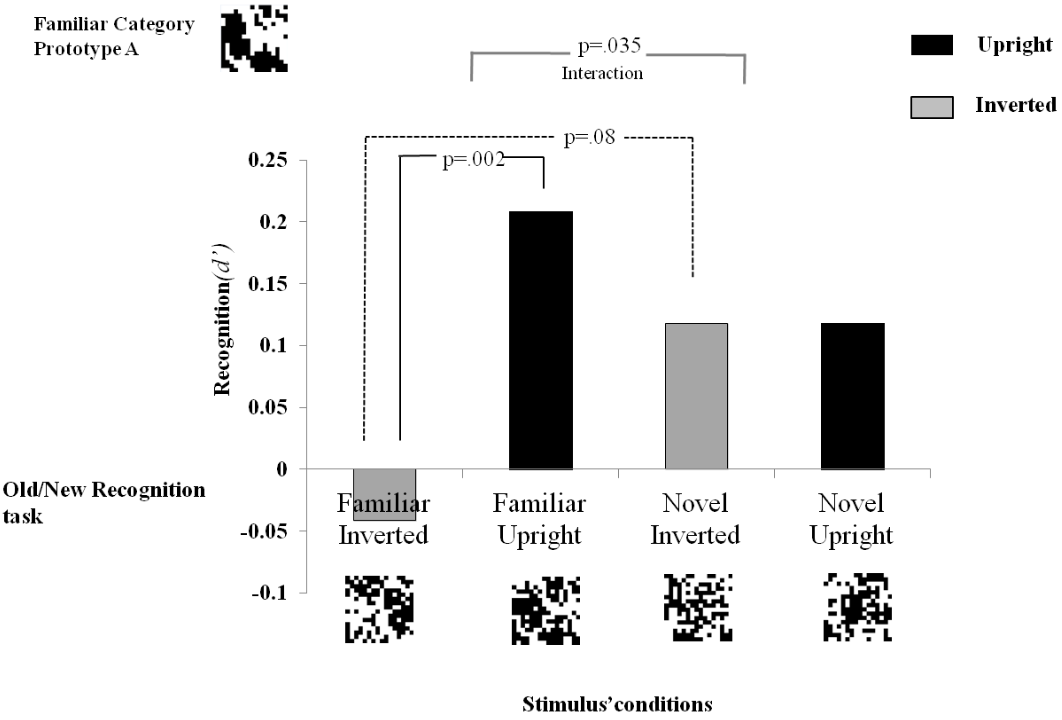


Figure.5.7.The X axis gives the four different stimulus' conditions, and the Y axis shows the mean d-prime scores for the old/new recognition phase in Experiment 12.

5.6.2.2 N170 analysis

N170 latency and amplitude analyses were run on electrode PO7 (Left occipito-temporal site) and on electrode PO8 (Right occipito-temporal site). I report the analysis from the study phase of Experiment 12. This is because significant differences on the N170 were not found in the recognition task; not an entirely unexpected result given that, if the modulation of the N170 reflects an effect of perceptual expertise, then this should occur when simply perceiving the stimulus, and should be easiest to detect during the study phase. This is because the effect should not be tied to having to do anything in particular, except perhaps attend to the stimulus, and by the recognition phase our familiarity manipulation will have been somewhat diluted by experience of all the stimuli in the study phase. Fig.5.8 shows the N170 recorded during the study phase of this experiment. Table.5.1 gives latency and amplitudes values for both study and recognition phases of Experiment 12. Because this was the first time I attempted to show an inversion on N170 for chequerboards two-tailed contrasts with an alpha of .05 were used to examine whether these effects were reliable

Latency analysis on **PO7**:

There was not effect of Familiarity, *F*(1, 31) = 0.178, MSE = 157.99, p = .337, as any effect of Orientation, *F*(1, 31) = 0.496, MSE = 121.980, p = .24. There was a trend towards significance for the interaction, *F* (1, 31) = 2.884, MSE = 65.931, p = .09. There was a trend for the N170 to familiar inverted stimuli to peak later than the one for familiar upright stimuli, *t*(31) = 1.656, SE = 2.302, p = .10. No significant difference in latency was found for novel stimuli *t*(31) = 0.419, SE = 2.538, p = .339.

Peak amplitude analysis **PO7**:

ANOVA revealed a trend for the main effect of Familiarity, *F*(1, 31) = 3.730, MSE = 0.563, p = .06, and a main effect of Orientation, *F*(1, 31) = 13.094, MSE =0.188, p = .001. The difference in peak amplitudes between upright and inverted chequerboards was significantly larger when the stimuli were drawn from a familiar category than from a novel one, Orientation by Familiarity interaction, *F*(1, 31)= 4.469, MSE = 0.282, p = 0.033. The effect of inversion was reliable for familiar categories, *t*(31) = 3.934, SE = 0.123, p < .001, with more negative amplitudes for inverted (-0.558μV) compared to upright (-0.072μV) chequerboards. For novel categories the inversion effect did not approach significance *t*(31) = 0.574, SE = 0.118, p = .285. Finally, there was a significant difference between novel inverted stimuli compared to familiar inverted stimuli, *t*(31) = 2.605, SE = 0.178, p = .014, with more negative amplitudes for familiar inverted (-0.558μV) compared to novel ones (-0.093μV).

Latency analysis on **PO8**:

Here as well ANOVA did not show any effect of Familiarity, *F*(1, 31) = 0.099, MSE = 96.957, p = .377, as any effect of Orientation, *F*(1, 31) = 1.736, MSE = 160.780, p = .09. Finally ANOVA revealed a trend for the Orientation by Familiarity interaction *F*(1, 31) = 3.619, MSE = 63.123, p = .06. A significant delay in the N170 was found for familiar inverted chequerboards, with them peaking 6ms later than that for familiar upright stimuli, *t*(31) = 2.539, SE = 2.215, p = .016. No significant difference in latency was found for novel stimuli *t*(31) = 0.093, SE = 3.014, p = .46.

Peak amplitude analysis **PO8**

ANOVA revealed a main effect of Familiarity, *F*(1, 31) = 6.077, MSE = 0.384, p = .019, and a main effect of Orientation, *F*(1, 31) = 7.229, MSE = 0.370, p = .011. Here as well the difference in peak amplitudes between upright and inverted chequerboards was significantly larger when the stimuli were drawn from a familiar category rather than from a novel one, Orientation by Familiarity interaction *F*(1, 31) = 6.66, MSE = 0.360, p = .015. The effect of inversion was reliable for familiar categories, *t*(31) = 4.178, SE = 0.134, p < .001, with more negative amplitudes for inverted (-0.557μV) compared to upright (0.005μV) chequerboards. For novel categories the inversion effect did not approach significance *t*(31) = 0.094, SE = 0.165, p = .46. Finally there was a highly significant difference between novel inverted stimuli compared to familiar inverted stimuli, *t*(31) = 3.800, SE = 0.143, p < .001, with more negative amplitudes for familiar inverted (-0.557μV) compared to novel inverted stimuli (-0.013μV).

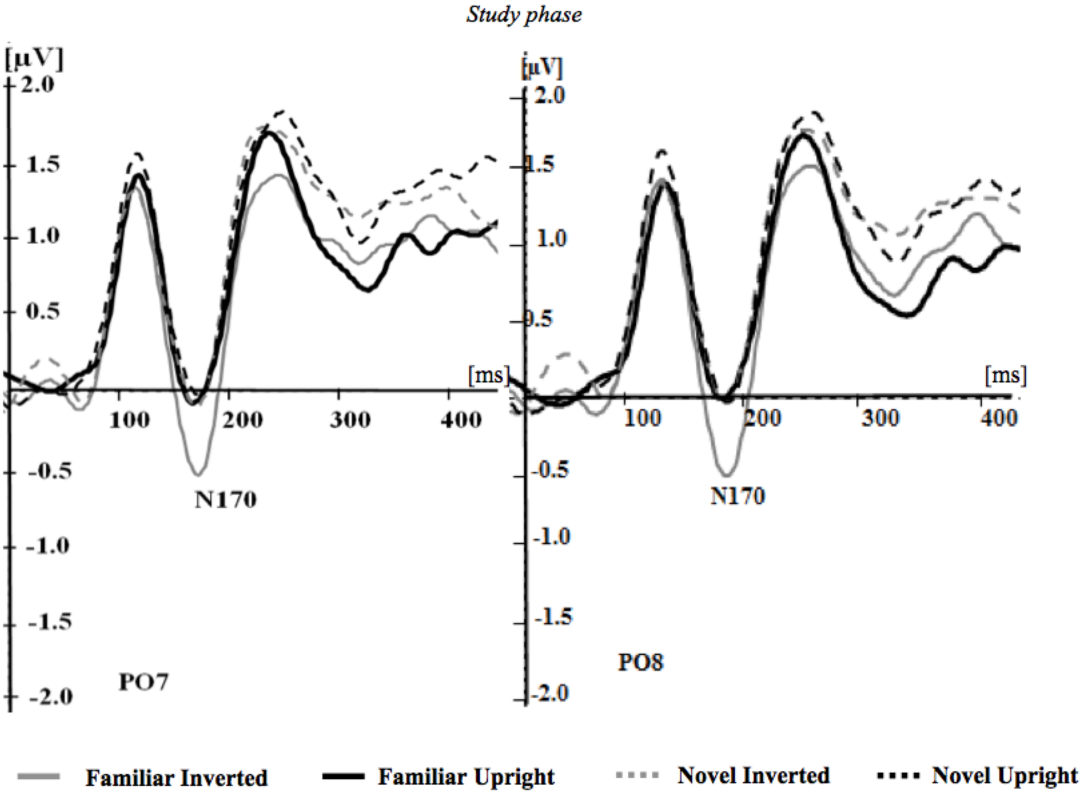
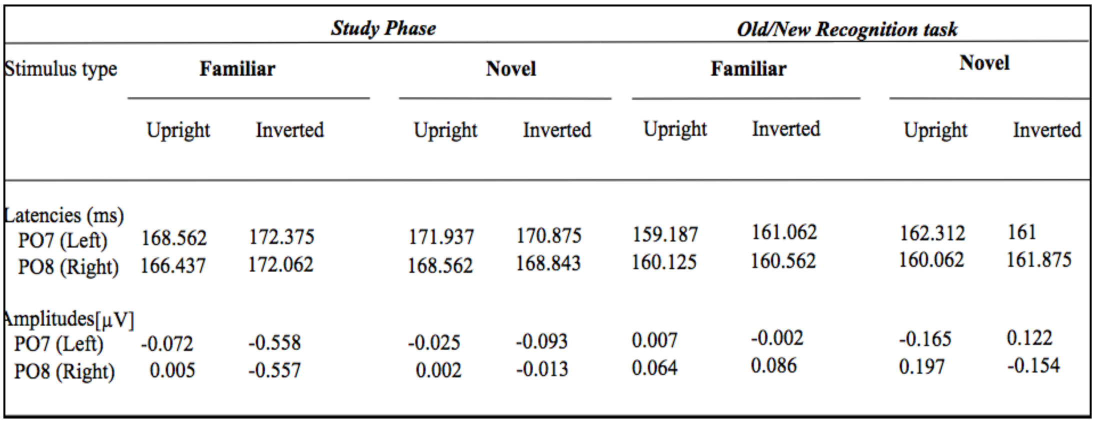


Figure.5.8. Waveforms obtained at electrode PO7 and PO8 during the study phase of Experiment 12.



	Study Phase				*Old/New Recognition task*			
Stimulus type	**Familiar**		**Novel**		**Familiar**		**Novel**	
	Upright	Inverted	Upright	Inverted	Upright	Inverted	Upright	Inverted
Latencies (ms)								
PO7 (Left)	168.562	172.375	171.937	170.875	159.187	161.062	162.312	161
PO8 (Right)	166.437	172.062	168.562	168.843	160.125	160.562	160.062	161.875
Amplitudes[μV]								
PO7 (Left)	-0.072	-0.558	-0.025	-0.093	0.007	-0.002	-0.165	0.122
PO8 (Right)	0.005	-0.557	0.002	-0.013	0.064	0.086	0.197	-0.154

Table.5.1.The data from the latencies and amplitudes on the N170 in Experiment 12.

5.6.3 Discussion

The behavioural results of Experiment 12 confirm I can obtain a significant inversion effect using stimuli drawn from familiar prototype-defined categories of chequerboards, and that this inversion effect is significantly greater than that for novel categories of chequerboards. Correspondingly, the ERP results show that chequerboards from familiar categories elicit a significant inversion effect in the N170, which is larger than that elicited by chequerboards from novel categories. Hence, I conclude that I have clear evidence of an electrophysiological inversion effect on the N170 for a set of stimuli entirely different from faces, and from other "natural" categories or Greebles. Additionally, the effect on the N170 found for Greebles was typically limited to the left hemisphere, whereas the analogous effect for faces is usually bilateral; my results show a strong effect of inversion on the N170 for both left and right occipio-temporal sites, providing a good match to the face data. I also note that the inverted chequerboards drawn from the familiar category produce a larger and delayed (in PO8) N170, also in line with the face inversion literature. The final point to make is that upright familiar categories and novel categories in both orientations elicited a similar N170. The real difference in the N170 is between the ERP to inverted chequerboards drawn from a familiar category and the other stimuli in this experiment, which suggests that it may be driven by the disadvantage consequent on seeing familiar chequerboards presented upside down, a disadvantage that is clearly present in the behavioural data.

5.6.4 General Discussion

In this chapter I have shown that the inversion effect with an artificially generated stimulus set can be obtained in a standard old/new recognition memory paradigm, that it is contingent on familiarisation with a prototype-defined category, and that the effect is made up of two components. I have confirmed the advantage for upright exemplars drawn from a familiar, prototype-defined category, and established that there is a disadvantage for inverted exemplars drawn from this category relative to suitable controls. I have also provided evidence for an N170 ERP signature for this effect. These results allow us to integrate the theory of perceptual learning originally due to McLaren, Kaye and Mackintosh (1989) with explanations of the face inversion effect first reported by Yin (1969).

Experiments 9a & 9b and 11a & 11b support the hypothesis that familiarity with a category defined by a prototype leads to an inversion effect in standard recognition paradigms with novel stimuli drawn from that category, and this does not happen after experience with a category that cannot be defined in terms of a prototype. Before accepting this assertion, however, we must establish that the pattern of performance seen in Experiment 9b was not simply a floor effect. In fact, the data argue against this interpretation. Performance overall in Experiment 9a was only marginally better than chance $F(1, 31) = 2.64$, $p = .057$, confirming the impression that the participants found the task very difficult. Overall performance in Experiment 9b was, however, significantly above chance, $F(1, 31) = 8.00$, $p < .005$, so, if anything, the task with the shuffled chequerboards was easier, and this is consistent with the categorisation data as well. It is unlikely, therefore, that the lack of an inversion effect with the shuffled chequerboards is due to a floor effect. There is, of course, one aspect of the stimulus construction used this time in the case of the shuffled chequerboards that does require further discussion. In the McLaren (1997) experiments, the rows were shuffled completely, and as such the likelihood of any given row remaining in its base position was rather low. This meant that the average of all the shuffled patterns was a set of vertical bands of varying degrees of grey (depending on the proportion of black squares in any given column), and this average was not actually a chequerboard, and so could not be considered as a prototype of the category. In the current experiments I only shuffled three rows (in 9b) and six rows (in 11b), to equate the number of squares changed (on average) with Experiments 9a and 11a, and this means that the chance of a row not being changed from its base position is rather high. Given this, the average of all the shuffled exemplars will now approximate a (somewhat blurry) chequerboard, and the claim that this is no longer a prototype-defined category is harder to sustain. Nevertheless, there is no doubt that the procedures with these stimuli lead to a quite different set of results to those obtained with the standard prototype + noise stimuli used in Experiments 9a and 11a.

A more detailed application of the MKM (McLaren, Kaye and Mackintosh, 1989; further developed in McLaren and Mackintosh, 2000; and McLaren, Forrest and McLaren, 2012) model to these stimuli helps make it clear why this should be so (see also Wills, Suret and McLaren, 2004 for a discussion of these issues in the context of categorisation rather than recognition). Take the stimuli of Experiment 9a first. Starting with a base pattern (the prototype), 48 squares are randomly chosen and then set to black or white at random to create each exemplar that will, on average, differ by 24 squares from the prototype. Consider a typical changed square in the middle of the stimulus. It will be surrounded by 8 squares that will mostly be those of the base pattern (on average 0.75 of a square of these 8 will have been changed). As a consequence of category pre-exposure, the MKM model tells us that the elements of a stimulus associate to one another, and that this allows them to predict one another, reducing their error scores, and that as a consequence their salience decreases. But, for a changed square, the predictions from the surrounding elements (which as near neighbours we assume will be important predictors for this square) will be incorrect, and so the square will have a relatively high salience because of its relatively high error score. This facilitates discrimination and recognition based on these changed features (which uniquely define the exemplars). In the case of the shuffled stimuli in Experiment 9b, because a row is moved as a whole, the squares either side of a changed square will be the same as usual for that square, and are good predictors of that square, even though its location in the stimulus has altered. The other surrounding squares are not such good predictors, and hence their influence will be less. The essential difference captured by this analysis is that shuffling rows leaves the changed squares in an exemplar relatively well predicted by other squares nearby, and this acts to mitigate any salience increase that would be gained from location specific prediction effects. Thus, category pre-exposure will not be expected to be that beneficial in the shuffled case, especially if we add in the fact that the location-specific predictions are themselves somewhat degraded by the shuffling process. The conclusion from this analysis is that, despite the greatly restricted shuffling algorithm used in the current experiments, the prediction that there should be no perceptual learning, and hence no inversion effect for the shuffled chequerboards in Experiments 9b and 11b still holds. Which brings us to the basis for the inversion effect in Experiments 9a, 10, 11a and 12.

Experiments 10 11a and 12 confirm the existence of the inversion effect found in Experiment 9a, and strongly suggest that it is made up of two components. These seem to be an advantage for the upright exemplars from the familiar category, and a disadvantage for the inverted exemplars taken from the familiar category.

This last finding seems to agree with the results I offered in Chapter 3 of this thesis. Thus, if we compare the pattern of results obtained in Experiment 4 of this thesis to those of Experiment 10, 11a and the behavioural part of Experiment 12, we can see that the inversion effect found for the scrambled faces is very similar to that found for chequerboards. In particular, in both cases (scrambled faces and familiar chequerboards) there is a clear advantage for the familiar exemplars in an upright orientation and a disadvantage for the same familiar exemplars when presented upside down relative to baseline. The implication of this finding is that the FIE can be explained by the fact that expertise with each of the features in a scrambled face or in a familiar chequerboard brings an advantage when those features are presented in their usual orientation. And, when these features are turned upside down, the benefit is lost and replaced by a clear disadvantage. The scrambled face data strongly suggest that this effect is not driven by the spatial relationships between features, and this is in no way contradicted by the chequerboard results (though they do not actively support this contention either).

Finally, the ERP results from Experiment 12 allow me to say a little more about the effect of familiarity with a prototype-defined category on inverted exemplars drawn from that category. It would seem to strongly affect the N170 for those stimuli, delaying it and increasing its amplitude. I speculate that this may be a direct neural correlate of the recognition / discrimination disadvantage suffered by these stimuli, but this is an issue that will have to await further research for confirmation. What I can say is that the effect on the N170 clearly correlates with the inversion effect found with familiar chequerboards.

Chapter 6: General Discussion

This Chapter 6 summarises and draws together the key findings from the experiments described in this thesis and discusses them with reference to the main debates in the field of face recognition introduced in Chapter 1: **i)** The debate as to whether faces are "special"**,** requiring special processes for their perceptual analysis or if our ability to recognise faces is just a result of our life **experience (expertise)** in perceiving them; **ii)** The debate as to the causes of the face inversion effect (FIE). In particular, many authors have proposed that processing of ***configural information*** is the basis of the FIE, whereas others have suggested that ***feature-based information*** might be more important. The chapter concludes by suggesting directions for further research on the FIE, and on the role of perceptual learning in the FIE.

6.1. Key findings in the context of the FIE and its causes.

6.1.1 *Single feature orientation information.*

I have arrived at a position that is rather different to the position with regard to the face inversion effect for pictures of faces first reported by Yin (1969). Many would ascribe the majority of this effect (if not its entirety) to the configural information in faces, specifically to the particular spatial relationships between the features that make up a face, and to our expertise in making use of the small variations in these relationships that individuate faces (e.g. Diamond and Carey, 1986). Instead, I have found that once the stimuli are appropriately controlled for the amount of detail present in them, performance can be (to a great extent) accounted for by the proportion of individual features that are upright in a stimulus. Experiment 2a hinted that this might be the case because the inversion effect did not entirely disappear after scrambling the faces, but it did not control for the amount of facial information present in normal and scrambled faces, making a comparison of the inversion effect in each difficult to interpret. In Experiment 2b, using smoothed normal faces and scrambled faces, the inversion effect was of a similar magnitude for both classes of stimuli, despite that fact that the normal faces still possessed configural information, information that had been severely disrupted in the scrambled faces. Experiment 3 demonstrated that the inversion effect for scrambled faces did indeed depend on the orientation of the individual features within the face, and in Experiment 4 I was able to replicate the substantial inversion effect for scrambled faces, and confirm that it disappeared if three of the six isolable features were themselves inverted to create a new type of scrambled stimulus.

6.1.1.2 The experimental manipulations.

It might be argued that my sets of scrambled faces used in Chapter 3 are themselves defined in terms of a prototype, and so in some sense possess configural information. But it is not structure that the participants would be familiar with when entering the experiment, and so any effect of expertise would be confined to the familiarity participants have for each one of the facial features seen in their usual upright orientation. Learning of the novel configuration used for my scrambled faces would, other things being equal, be expected to happen as rapidly for the inverted configurations as for the upright ones, and so could not be expected to contribute to the inversion effect. My conclusion is that the inversion effect observed with scrambled faces is mostly driven by single feature orientation information. If this information (within a set of faces that share a novel configuration) is disrupted, then so is the inversion effect.

Another advantage of the manipulations in Experiment 2a and 2b is that they are drastic. By scrambling all the features within a face I made sure that all the configural information (in the sense of what Diamond and Carey term first and second order relational information) normally seen in a face was completely changed. It is important to underline this, because if we look at the literature, many studies have used sets of distorted faces, where for example, the eyes were sometimes shifted apart and the mouth moved upwards, and sometimes the eyes were closer together and the mouth shifted downwards (e.g., Leder & Bruce, 2000; Rhodes et. al, 1993,). However, the problem with these manipulations is that if you average all the distorted faces you will get something approaching a normal face with the usual configural information. Thus, the manipulation is, in some sense, simply one of adding noise, with the disruption of configural information taking place on a relatively minor scale. Another advantage of my scrambling manipulation was that by moving the randomly selected feature to the space left empty by the previously moved feature I ensured that, for example, the eyes would never align as in normal faces. I believe this to be a better manipulation than that used by some other studies in the past, where the scrambling process was based on splitting the face into three internal regions, such as the mouth, nose, and eyes, and the shuffling was being done by moving regions as a whole, giving a final result that always left the configural information between the two eyes untouched (e.g., Donnelly et al., 1994). For this reason, I believe that my scrambling process was particularly effective in disrupting participants ability to make use of the configural information in a face, making it all the more remarkable that the inversion effect not only survived, but was comparable in size to that in normal faces once a suitable level of smoothing was applied.

6.1.2 Implications for face inversion studies

6.1.2.1 *Rakover and Teucher (1997)*

On the basis of the results I presented in Chapter 3, the position taken by Rakover and Teucher (1997) attributing the inversion effect to the proportion of individual features in an upright orientation, is one that receives considerable support. My experiments are the first to manipulate feature orientation in the context of a scrambled face and compare performance to properly controlled standard face images, and they are entirely congruent with Rakover and Teucher's results with isolated features and the analysis of the inversion effect that follows from these results.

6.1.2.2 Gold, Mundy and Tjan (2012)

In many ways my results are also consistent with those of Gold, Mundy and Tjan (2012), who found that recognition performance for an upright or inverted face could be satisfactorily predicted from performance on isolated features, but that performance to those isolated features in an inverted face was poorer. Thus, the configuration "helped" feature processing in some way, and this assistance was lost on inversion. My use of scrambled faces eliminates this effect of configuration, and enables us to see the "pure" effect of feature orientation in upright and inverted scrambled faces. However, I appear to disagree with their results in one minor respect, in that I found in Chapter 3 (Experiment 2b) that at least some of the benefit accruing from the standard configuration (i.e. a normal face) applied to both upright and inverted faces, not just to the upright face. The idea of the configuration in an upright face helping feature processing, and this benefit being lost on inversion is, however, entirely in line with my later findings with regard to the role of first order configural information in the FIE.

6.1.2.3 Yovel and Kanwisher (2004) and Rossion (2008)

My results are also consistent with other studies that suggest that the inversion effect has a substantial component driven by individual features (e.g. Yovel and Kanwisher, 2004; Riesenhuber, Jarudi, Gilad and Sinha, 2004), but these studies have been criticised by Rossion (2008) who argued that they underestimated the contribution from holistic processing. Yovel (2009) and Riesenhuber and Wolff (2009) have responded to these criticisms, and Rossion (2009) has replied in turn. All I feel able to contribute to this debate is to note that 1) based on my evidence there is undoubtedly a contribution from individual features to the FIE and 2) this debate, and the evidence I present in Chapter 4 clearly indicates that it would be unwise to rule out a contribution from configural information as well. The reason I feel able to commit to 1) is that my demonstration of an FIE in scrambled faces is not subject to the criticisms made by Rossion of other demonstrations of this type, if I assume that holistic processing is entirely disrupted by this manipulation, and the rank ordering of performance by number of features in an "upright" orientation is also consistent with my claim. Conclusion 2) clearly indicates that further research on the role of configural information in the FIE is needed. For now, I speculate that first order configural information can engage some type of holistic processing which confers an advantage for upright faces (Chapter 4, and see previous section). There is also the possibility that second order relational information in a normal face confers an advantage irrespective of orientation, but I feel my evidence falls short of establishing this. The finding that suggests this might be the case is in Chapter 3, Experiment 2b, where performance on normal faces was superior to that on scrambled faces in both upright and inverted orientations. If we now combine this result with those from Chapter 4, which require us to say that first order relational information confers a benefit (in terms of recognition performance) that only applies to upright faces, then this leaves second order relational information as the remaining candidate to explain the result from Chapter 3.

6.1.3 Configural information and FIE

The experiments reported in Chapter 4 of this thesis answered the question put in Chapter 3. Thus, configural information does affect the FIE. Taken together the results from Chapter 4 confirmed that it is possible to obtain an inversion effect when all the configural information is disrupted,. But, in addition, they have shown that it is also possible to obtain an inversion effect when the single feature information and the second-order relational information are disrupted by keeping the first-order relations as close as possible to normal. This result was hinted at in Chapter 2 when, by using the original Thatcherisation technique pioneered by Thompson (1980) the FIE was not entirely eliminated. The experiments reported in Chapter 4 used a more drastic manipulation and broadly supported the pattern of results already shown in Chapter 2. However, this time, with better control of the single feature orientation information and better control for any effect of luminosity or local information, the New Thatcherised faces used in Experiments 6 and 7showed a clear trend toward a significant inversion effect, and in Experiment 8 I obtained a strong inversion effect for those stimuli. The implication of this finding is that there seems to be two sources of information affecting facial recognition on inversion, and first order configural information is a candidate for one of these sources.

6.1.3.1 Theories of Holistic processing of face recognition.

6.1.3.2 Mondloch and Maurer (2002)

The results in Chapter 4 find some support in studies on holistic information and could potentially suggest that first-order information leads to holistic processing of the face, which then brings an advantage in recognizing upright faces. This result would fit well with some other results found previously by Mondloch and Maurer (2002) on the CFE (composite face effect). Mondloch and Maurer (2008), suggested that holistic processing has been tuned to upright faces. In their study on CFE they found that holistic processing decreased linearly over the entire range of orientations but remained significant when faces were oriented at 30 degrees or 60 degrees from upright. When faces reached a sideways orientation (90degrees), the CFE was present in the means but no longer statistically significant, and, with further rotation, it disappeared altogether. The results are especially convincing because the diminution of holistic processing was revealed by increased accuracy on "same" trials as the faces were rotated further from upright, contrary to the usual decrease in accuracy of face processing with rotation (Collishaw and Hole 2002; Mondloch et al 2002; Valentine and Bruce 1988), but just as would be predicted if the holistic processing that makes these trials hard for upright faces were diminishing. The results extend the many previous reports that the CFE seen for upright faces is not present for inverted faces (Carey and Diamond 1994; Hole 1994; Young et al 1987).

6.1.3.3 Hole et al., (1999)

As I mentioned previously in the discussion of Chapter 4, Hole et al., (1999) investigating the CFE suggested that holistic processing could be elicited by anything that roughly conforms to the basic plan of a face, and it is holistic encoding that establishes that it is a face that is being perceived, as opposed to some other kind of object. However, if I allow a robust version of Hole et al' s (1999) holistic processing construct, one that would imply that my sets of scrambled faces could be identified as faces and so generate an inversion effect, I would then have to explain why this holistic processing ceased to apply to the 50% Feature-Inverted and Scrambled faces. If the explanation was that a certain number or proportion of facial features had to be upright for holistic processing to apply and only the upright Scrambled faces met this criterion, then I would be left in some difficulty in explaining why performance on the 50% Feature-Inverted and Scrambled faces is superior to that on the Inverted Scrambled faces – surely they should be the same? Given that this is not the case,, it could be that the strong holistic construct suggested by Hole et al., (1999) is elicited when a face shows at least some evidence of first-order relational information. However, it is clear that further research on the role of first-order relational information and its link with holistic process in the FIE is needed. I will suggest later on in this chapter some potential studies that could be conducted to investigate this.

6.2. Key findings in the context of general mechanisms of face recognition.

6.2.1 Perceptual learning for a familiar category under inversion

In the experiments reported in Chapter 5 I have demonstrated that I can obtain a strong inversion effect in a recognition task contingent on use of exemplars drawn from a familiar prototype-defined category. This effect can be decomposed into an advantage for upright exemplars drawn from a familiar category, and a disadvantage for inverted exemplars drawn from a familiar category. This inversion effect has a neural correlate in the N170, which seems to predominantly reflect the disadvantage for inverted exemplars drawn from a familiar category.

The implications of these findings are far-reaching, because they suggest that the standard face inversion effect could also be due to a combination of two components, an advantage for upright faces (relative to other classes of stimuli), and a disadvantage for inverted faces. In fact, we can note that it is only experiments of the type reported here which can really be said to establish this possibility, as the appropriate baseline for standard face inversion experiments is hard to determine.

6.2.1.1 Advantage for upright familiar exemplars.

The explanation of the advantage for the upright exemplars drawn from the familiar category has already been given in Chapter 5, but bears some repetition. During categorization, the prototypical elements common to the exemplars of a given category will be routinely exposed, and so will lose salience according to the MKM model. By way of contrast, the elements unique to each exemplar (which the subjects will have less exposure to and will be less well predicted by other elements of the stimulus) will still have relatively high salience. Hence, the structure of this prototype-defined category will ensure that differential latent inhibition of common and unique elements can occur, and this leads to perceptual learning, which in turn leads to an improved ability to recognize upright exemplars of the familiar category, because this depends on using the unique elements of exemplars rather than the ones they share in common. This simply represents an instance of the type of effect reported by McLaren, Leevers and Mackintosh (1994), and also seen in Graham and McLaren (1998). This advantage would be lost on inversion, because participants are not familiar with those exemplars in an inverted orientation, and hence the unique elements of an exemplar would no longer enjoy any salience advantage over the elements common to most exemplars and the prototype. On the other hand, when subjects are presented with exemplars of a novel category that they have not been pre-exposed to, these mechanisms do not apply (at least not straight away), so there will not be any benefit in recognizing exemplars of that novel category in their upright orientation. Thus, no significant inversion effect would be expected, because an inverted novel chequerboard is just another novel chequerboard.

This explanation of the inversion effect found with exemplars drawn from a familiar category in terms of perceptual learning works well when considering the advantage enjoyed by upright exemplars drawn from that category. But this leaves us with evidence from four studies that familiarity with a prototype-defined category will lead to inverted members of that category being less easily discriminated (McLaren, 1997) or recognized (Chapter 5 of this thesis) than novel controls.

How am I to explain this disadvantage? The perceptual learning analysis offered so far simply suggests a return to baseline performance, not something worse. What is it about familiarity with a prototype-defined category that leads to poorer discrimination or recognition of inverted exemplars drawn from that category?

6.2.1.2 The disadvantage for inverted familiar exemplars

McLaren (1997) speculated that this effect might be connected with the finding that participants were able to categorize exemplars even when they were inverted. Tests administered at the end of the experiments in that paper revealed that for both prototype-defined categories and shuffled categories, participants were able to classify inverted exemplars as members of the correct category with above chance accuracy (59% in both cases, compared to 66% and 70% for upright exemplars). I can see two possible mechanisms that might follow from this and explain the disadvantage for inverted exemplars drawn from a familiar category.

The *first* possible mechanism is that, if participants are able to classify inverted exemplars as an "A" or "B", then this in itself can have consequences. If discrimination between an exemplar from one category and an exemplar from the other is required then a "learned distinctiveness" effect (Honey and Hall, 1989) can be expected, whereby the different labels attached to each exemplar aid in their discrimination. But when the discrimination is within category, a "learned equivalence" effect can be expected instead, which enhances generalization between the stimuli, making discrimination more difficult. Admittedly, this effect can be expected for both upright and inverted exemplars drawn from a familiar category, but the upright exemplars benefit from perceptual learning as already outlined, which more than compensates for this effect. When this compensatory effect disappears on inversion, the cost of "equivalence" manifests and this is why the familiar inverted exemplars are poorly recognized compared to novel exemplars. This account is plausible, and there is other evidence for the mechanisms involved, but it does suffer from the observation that no such effect was noticeable in the experiments with shuffled stimuli (or in the 1997 equivalent), and it should manifest there because the effect is not dependent on the category being prototype-defined.

The *second* possible mechanism I can think of does depend on category structure. In the case of prototype-defined categories, the ability to categorize inverted exemplars implies that features present in the these exemplars are capable of calling to mind some representation of the structure of that category, which will correspond to the upright, prototypical structure experienced during training. According to the MKM theory, it is exactly this ability that allows the differential salience of the unique elements of an exemplar to manifest and support better learning and memory. But, in the case of the inverted exemplars, the predictions made by retrieval of the prototypical structure will often be incorrect, and will not correspond to the layout of the black and white squares. Thus the elements that become differentially salient will be randomly determined, and will more often be those that are common to most exemplars (simply because there are more of them), rather than unique to any one of them. This will have the effect of adding unwanted noise to the discrimination, making it more difficult – hence a disadvantage for inverted exemplars drawn from a familiar category will emerge. Note that this effect will be beyond that expected for novel stimuli, as in that case the elements will be uniformly unpredicted rather than randomly (and often incorrectly) predicted.

6.2.2 Implications for theories of perceptual learning.

6.2.2.1 Mundy, Dwyer and Honey (2006), Mundy, Honey and Dwyer (2007), Dwyer and Vladeanu (2009) and Mundy, Honey and Dwyer (2009)

The advantage of the approach I have taken in extending the account given by McLaren (1997) to my current data, is that it does seem to have the potential to explain my results and to explain the role of perceptual learning in the face inversion effect. Can other theories of perceptual learning provide different explanations of the phenomena reported in this paper? I particularly have in mind here recent research by Mundy, Dwyer and Honey (2006), Mundy, Honey and Dwyer (2007), Dwyer and Vladeanu (2009) and Mundy, Honey and Dwyer (2009) that makes a case for a comparison process in perceptual learning in humans. This research with human participants (often using faces as stimuli) shows that simultaneous or alternated presentation of similar stimuli leads to better discrimination in a subsequent test phase. The inference is that the ability to compare the stimuli that have to be discriminated later leads to stronger perceptual learning compared to controls that are exposed to these stimuli equally often, but without the opportunity for comparison (often in what is referred to as a "blocked" schedule of exposure).

My response to these studies is to first note that McLaren, Forrest and McLaren (2012) have shown that the most recent version of MKM, in the form of the MKM-APECS hybrid model, can simulate the blocked vs. alternated effect. Thus, the evidence for a comparison process based on this type of result is not conclusive. But, if we take the comparison process account as a given, what are the implications for my results? During categorization, the participants have the opportunity to compare exemplars (successively – each exemplar is presented on its own) both between and within categories. This would lead to them being better able to discriminate both within and between categories as a result of this opportunity for comparison (assuming it somehow generalizes to new exemplars) and could then predict an advantage for upright exemplars drawn from a familiar category in later recognition. In this respect the comparison account's predictions do not differ greatly from those already in play, and they would doubtless go on to predict that inversion would lead to a loss of perceptual learning. In terms of the basic effects, then, the comparison account could provide a good explanation of the observed phenomena. The problems for this class of account appear when we consider the additional effects established by this thesis. I cannot think of any particular reason for the comparison account to predict that inversion of exemplars drawn from a familiar category would lead to worse performance than to novel exemplars (beyond some general account in terms of learned equivalence of the type I rejected earlier), and this seems to me something of a challenge for this class of theory. Given that this result is now established, it would be greatly to the credit of any theory of perceptual learning to offer at least some explanation for the effect. At present, to my knowledge, only the MKM-based theories seem capable of doing this.

The second problem for this class of account is one that it shares with the attempt to appeal to learned equivalence to explain the disadvantage in recognizing inverted exemplars drawn from a familiar category. This class of theory would seem to predict an inversion effect whether the familiar category be prototype-defined or not, and I have shown in three experiments that, in line with McLaren (1997), this is not the case. If the familiar category is constructed by generating exemplars from a base pattern by shuffling the rows, then no inversion effect is observed in a study-test recognition paradigm. But, as things stand, I can see no reason to predict the lack of an inversion effect with shuffled stimuli, and the Category type x Orientation x Familiarity interaction reported in Chapter 5.

6.2.4.2 Response to Jones and Dwyer, 2013; Wang, Lavis, Hall and Mitchell, 2012

My final issue concerns a number of recent studies that have shown that perceptual learning can, under some conditions, simply involve participants learning where to look, rather than in any way implying some enhancement of stimulus discriminability (Jones and Dwyer, 2013; Wang, Lavis, Hall and Mitchell, 2012). Could this explanation apply to the experiments reported in Chapter 5, so that the inversion effect is due to participants learning where to look during categorization training, and then applying this strategy during the recognition experiment with some success in the case of the upright familiar exemplars, but suffering because of it when dealing with inverted familiar exemplars? Whilst I would readily acknowledge that strategies of this kind are possible in many perceptual learning experiments, I do not believe that they are in play here. The stimuli are all randomly generated in my experiments, each exemplar is unique, and there is no particular region to focus on to detect individuating features for any stimulus set. The squares changed vary from stimulus to stimulus, making any such strategy unlikely to succeed. It might be that categorization training encourages participants to look at certain regions of a stimulus to distinguish members of category A from those of category B, but this is unlikely to have any relevance to discrimination within one of these categories, which is what is tested in the recognition phase. Finally, given that the shuffled stimuli were more easily categorized, and if this is to be taken as an index of success in learning the necessary strategy, surely the inversion effect should have been larger in these stimuli in Chapter 4 rather than non-existent? I conclude that I have no evidence in my data that participants' enhanced performance on exemplars drawn from a familiar category is due to learning where to look, or that their impaired performance on inverted exemplars from the same category is due to this type of learning. Rather, it would seem that an explanation in terms of enhanced stimulus discriminability is to be preferred.

6.2.3 The inversion effect and the N170

The ERP results from Experiment 1 of this thesis provide neural correlates of the behavioural findings. In particular, in the study phase where participants were only asked to look at the faces and try to memorize them, analyses on both the amplitude and latency of the N170 gave a larger inversion effect for normal faces than for manipulated faces, and this result was highly significant for the latencies. Running the same planned comparisons on the ERP data as used for the behavioural data produces a very similar pattern of results, i.e. a strong inversion effect for the normal faces, and a reduced one for Thatcherised faces.

In Experiment 12 of this thesis the effects observed on the N170 clearly correlate with the inversion effect found with familiar chequerboards. In a similar fashion to the results obtained in Experiment 1, here the familiar stimuli show a larger and delayed inversion effect on the N170 compared to that for baseline. I have underlined the word "baseline" because it needs a particular explanation in the case of my face experiments. This is because, as was shown in Chapter 4, Thatcherised faces cannot be considered as a baseline. But actually, by means of better control of the Thatcherisation of the stimuli, the experiments reported in Chapter 4 showed how those stimuli can still elicit a strong inversion effect. Thus, the real comparison between the EEG studies for faces and chequerboards should have been made by using (in the case of faces) the 50% Feature-Inverted and Scrambled faces to investigate their electrophysiological correlates. Results from Experiment 12 replicate and extend the earlier demonstrations of such a correlation with Greebles (Rossion et al., 2002) however this time using stimuli that do not share any similarities with faces and that they are not perceived as mono-orientated before participants had been trained in seen them in one orientation. These results also fit in rather well with the effect on the N170 found by Roxane et al., (2006). The authors found a larger N170 for inverted faces compared to other objects (e.g. chairs, houses, cars) and animals (apes) in both upright and inverted orientations, all of which elicited a significantly smaller N170 (in some cases even smaller than that for upright human faces). More evidence in support of this finding comes from studies of inversion as modulated by ethnicity on the N170. Vizioli et al., (2010) showed that the N170 amplitude for same race inverted faces was significantly larger compared with upright same race and upright and inverted other race stimuli. Thus, the presentation of unfamiliar faces, in this case faces taken from an unfamiliar ethnic group, attenuates the effect of inversion on the N170. Additionally, the behavioural test showed that accuracy for inverted familiar race faces was significantly lower than for the other stimuli. These results, taken together with mine (Experiment 12) seem to suggest that the largest amplitude for the N170 is correlated with the lowest behavioural performance for familiar inverted exemplars.

6.4. Further research

Throughout this thesis, in addition to the main findings as to the cause of the FIE and on the expertise account of face recognition, there have been some assumptions that would require additional support to be considered as established.

6.4.1 The analogy between chequerboards and scrambled faces

One example is the claim made in Chapter 5 about the analogy between the results obtained with chequerboards (Experiments 10 and 12) and those with faces (Experiments 3 and 4). In support of this analogy there are the very similar patterns of results obtained in studies with both faces and with chequerboards. There are three main similarities that support the analogy: **i)** As strong an inversion effect with chequerboards as that for scrambled faces; **ii)** An advantage for familiar upright stimuli; **iii)** A disadvantage for familiar inverted stimuli. I believe there is one main issue that needs to be addressed in the future. This is the fact that it has not been possible so far to establish a definitive baseline for my face experiments able to match the characteristics the novel category of chequerboards in my perceptual learning experiments. The set of 50% Feature-Inverted and Scrambled faces are currently my best candidate to be the face baseline, but more research is needed to establish this to be the case.

6.4.1.2 *Testing for a face baseline.*

I note that, on the one hand I have for the chequerboard experiments the correlates between my behavioural results and the N170 in the ERPs, but on the other hand for the scrambled faces experiments I have only the behavioural results. It would be interesting and informative to run an EEG study in which the same stimuli used in Experiment 4 would be used again. The aim would be to investigate whether the results on the N170 would match those obtained in Experiment 12. It is important to establish if this is so, not only to allow a closer analogy between faces and chequerboards, but also to know if the 50% Feature-Inverted and Scrambled faces set of stimuli could be considered as a face baseline. In fact, I note that the novel set of chequerboards, which works perfectly as a baseline in my experiments, shows no differences on the N170 under inversion, plus we have the fact that this novel set of stimuli elicits a similar N170 to that for familiar upright stimuli. Thus, if 50% Feature-Inverted and Scrambled face stimuli would show similar neural correlates to that shown by novel categories of chequerboards that could help establish them as good candidates for the face baseline.

6.4.2*The analogy between chequerboards and normal faces*

If the analogy between scrambled faces and chequerboards seems to be very close, when I compare normal faces with chequerboards it is apparent that there are still differences that need to be explained. In the domain of the inversion effect the data collected so far in my experiments seem to suggest that the size of the FIE for chequerboards could be similar to that for scrambled faces and for normal faces. However, normal faces show a much higher level of recognition performance compared to my familiar sets of chequerboards. Obviously a few minutes in a laboratory being exposed to sets of chequerboards is not comparable with a lifetime's expertise in seeing faces at different angles, with different expressions and with all the connotations and importance that faces posses in respect of our social life. This could perhaps explain why normal faces are far better recognised than my sets of chequerboards. One way to try to address this issue comes from non-invasive brain stimulation techniques. In particular, in the last few years there have been several studies using tDCS (transcranial direct current stimulation) to enhance language and mathematical ability, attention span, problem solving, memory, and coordination. My plan is to see if this will also enhance perceptual learning and lead to a larger FIE, or one that develops more rapidly, with artificial stimuli such as chequerboards.

6.4.2.1*tDCS, perceptual learning and inversion effect.*

Transcranial direct current stimulation is able to influence the excitability of human visual and motor cortices focally, reversibly and non-invasively. Early animal studies have shown that weak cathodal stimulation decreases cerebral excitability due to membrane hyperpolarization, while anodal stimulation increases it through membrane depolarization (Pascual-Leone et. al, 1994). Thus, the method can be used to reduce or increase the excitability of a particular cortical area (Purpora, 1965). In addition, the literature on the N170 indicates that occipito-parietal areas are the most involved in eliciting a larger N170 for faces, or Greebles, or in the case of my study for chequerboards, than for other equally complex stimuli. Thus it would be useful to employ tDCS to investigate this phenomenon. If occipital-parietal areas are necessarily involved in the inversion effect, applying anodal or cathodal stimulation over this region should increase or decrease the size of the inversion effect.

An experiment could be conducted either by using two participant sample groups, or by using a within-subjects design if this seems feasible. The control group (sham stimulation) would be presented with an old/new recognition task with facial stimuli in upright and inverted orientations, and behavioural and ERP responses would be recorded. Obviously this group should show a strong inversion effect behaviourally, and a strong effect of inversion on the N170 (smaller amplitude for upright faces compared to inverted) in occipital-parietal scalp areas; 2) the Experimental group could instead be given cathodal stimulation over the occipital parietal areas during the study phase (normally ERP studies show the P08 as being most involved in eliciting the N170). Following this, they will be presented with an old/new recognition task in which ERPs will be recorded. Potentially near complete disruption of the inversion effect is expected for the experimental group in terms of both behavioural results and on the N170. I would then move on to a second experiment using a similar experimental procedure, but this time testing two groups of participants on recognition for chequerboards. Now the experimental group would be given anodal stimulation during pre-training with the chequerboards, aimed at making the inversion effect stronger in the familiar category, and also producing a larger effect on the N170 compared to controls. A comparison between the two experiments might show no effect of inversion for faces after cathodal stimulation, and a strong effect of inversion for chequerboards following anodal stimulation. Thus, the demonstration would be that by increasing neuronal excitability in areas normally believed to be specific for faces, I can obtain strong inversion effects and large N170s for chequerboards, whereas decreasing stimulation in the same areas could actually disrupt any inversion effect for facial stimuli. These results would strengthen the analogy between faces and chequerboards and would also speak to the neural basis for perceptual learning. Experiments of this type are currently underway at the Institute of Cognitive Science at ECNU Shanghai under the supervision of Prof. Ku.

6.4.2.2 The chequerboard manipulations.

As I previously mentioned in this chapter, more research needs to be done in order to understand the role that configural information has for the FIE. Thus, I propose that it would be important to test my sets of chequerboards in the same way as I tested the faces. What I am suggesting is to Thatcherise and scramble the chequerboards. So, a potential experimental design could involve presenting participants with a categorisation task in which they familiarise themselves with the main features of the chequerboard exemplars of that category. Then, in the study phase, I would present the subjects with a familiar category of chequerboards in which the exemplars have been Thatcherised as I did for New Thatcherised faces. This could be done by selecting 50% of the features in all the exemplars drawn from the familiar category of chequerboards and turning them upside down. There are two main aims of this study: **i)** to see if the inversion effect still survives Thatcherisation as is the case for faces; **ii)** to also investigate any potential interaction with conditions using a novel category of chequerboards similar to that between New Thatcherised faces and 50% Inverted and Scrambled faces. The precise algorithm for performing this manipulation on chequerboards has yet to be finalised and will itself need to be the subject of some research.

6.4.3 An infra-human analogy of the inversion effect

Another area of research concerning spatial representation of configurations is that related to spatial navigation in animals such as the rat. Here, the animal is tested using a paradigm such as the radial maze or the Morris water maze, and the results from many experiments suggest that the rat uses the configuration of the extra-maze landmarks to guide its choice of arm or location to visit. Results in these paradigms show that rats can quickly learn to approach a given location, e.g. a hidden platform in the water maze. These findings point to performance based on spatial memory, a memory for a specific place, which would be the product of the spatial processing capabilities of a particular species and the discriminability of the objects in that environment. In one of their studies Prados, Chamizo and Mackintosh (1999) used a large circular swimming pool modelled after that used by Morris (1981). The experimental procedure included three types of trials: pretraining, preexposure, and escape training. The pretraining consisted of inserting the rat into the pool, without any landmarks but with the platform present, and allowing the rat to swim around and find the platform. The preexposure trials took place in the observation compartment, preventing exploration, but in the presence of the landmarks. For the “single group” rats the compartment was open facing a single landmark, whereas for the “configural group” the compartment was open pointing midway between two landmarks. Finally, for the escape trials, the procedure was the same as the pretraining trials, however this time the four landmarks were always present. Theories that rely on cognitive maps would expect that the chance to view the landmarks sorrunding the pool would definitely facilitate the rats in building up a map of the pool and surroundings and make their escape from the pool much easier.

However the results from the three experiments instead supported an associative analysis showing that preexposure to landmarks can make it either easier or harder for rats to subsequantly find the submerged platform located in a fixed position (relative to the landmarks) inside the pool. In particular, these results have been interpreted in terms of latent inhibition (Prados, Chamizo and Mackintosh,1999). According to perceptual learning theories, preexposure reduces the salience or associability of the preexposed cues. The explanation for the results obtained in the first two experiments in this study is that where preexposure is to the common features (configural group) , it reduces the salience of these common features more than the features unique to each of the landmarks (McLaren, Kaye and Mackintosh, 1989; McLaren & Mackintosh, 2000) facilitating discrimination. But exposure to the unique features produces latent inhibition to them, reducing discriminability and learning. Hence the observed benefit for the "configural" over the "single" group. It seems to me that the analogy with face inversion studies could be easily investigated using something like this paradigm. As an example, consider what would happen if, after preexposure to the landmarks, we were to turn them upside down (or turn some of them upside down). Obviously the landmarks used would have to have a distinct vertical orientation for this manipulation to be meaningful. Would this negate any effect of preexposure? If the landmarks are, in order, ABC and D, if B and D are rotated after exposure to points midway between the landmarks' original positions would this have more impact than exchanging C and D? Would exchanging B and D have an effect similar to inversion? By asking what would rotating some of the landmarks relative to others do to performance I would attempt to generate an analogue of inversion under conditions of spatial learning rather than face or object recognition. The results from these experiments could cast light on the claim that the inversion effect is not to do with something specific to faces but can be explained by general mechanisms of spatial learning that we share with other animals. Experiments of this type are currently underway in Barcelona under the supervision of Prof. Chamizo.

6.4.4*Perceptual Learning and the Composite Face Effect*

To conclude this section on further research, I would like to extend my work on perceptual learning and face inversion to another robust effect in the field of face recognition. Thus, the composite face effect consists of the difficulty that adults show in recognising the top half of a face when it is aligned with a new bottom half, unless holistic processing is disrupted by misaligning the two halves (Mondloch & Maurer, 2008).There is some evidence that the tuning of holistic processing for faces that are upright or nearly so is likely toresult from experience. Indirect evidence comes from studies comparing the size ofthe CFE and of the whole/part advantage for faces of the subjects' own race or ethnicgroup, a category with which they have had years of experience, and another race, a category with which they have had minimal experience and for which their abilityto differentiate and remember individual identities is lower. Adults process faces from their own race and ethnic group more holistically than faces from a less familiar race/ethnic group, as measured by the CFE(Michel et al 2006a, 2006b; Tanaka et al 2004). There may be a 'critical' period for this development. Adults do not show a CFE for nonsense objects on which theyhave not been trained (Gauthier and Tarr 2002) and it is difficult to induce a CFE fornonface objects even with extensive training.

Thus what I am suggesting is that it could be interesting to use the sets of chequerboards employed in this thesis and manipulate them as in the case of the CFE. After a categorisation task, participants could be presented with a study phase that included a composite set of aligned chequerboards, and a set of misaligned chequerboards. Specifically, the top half of each stimulus would be drawn from exemplars of the familiar category of chequerboards, whereas the bottom half would be selected from exemplars either of a novel category of chequerboards or from a different familiar category of chequerboards. The CFE would predict a better performance in recognising misaligned stimuli compared to aligned ones. As baseline I could use a set of aligned and misaligned exemplars drawn from a novel category of chequerboards. Thus, no composite effect would be predicted for this latter set of stimuli. Finally, a further study could use the same set of composite familiar chequerboards but this time showing some of the stimuli in an inverted orientation. This time the composite effect for misaligned familiar chequerboards should disappear. These experiments could help to provide support for the role that holistic processing has in face recognition.

6.4.5 To sum up

In conclusion, the experimental work reported in this thesis investigated two main claims: the first was made by Yin (1969), and asserted that the face inversion effect, which is a reduction in recognition performance to inverted faces compared to upright, is specific to facial stimuli; The second one was made by Diamond and Carey (1986), and asserted that the face inversion effect is based on the expertise that individuals have for second-order relational information. The main findings of this thesis are threefold: 1) It is possible to obtain a strong inversion for sets of faces which have all their configural information disrupted, but still have what I call the single feature orientation information unaltered. 2) I successfully extended McLaren’s (1997) findings with chequerboards to an old/new recognition paradigm. Thus I showed a significant inversion effect for an artificial set of non mono-orientated stimuli that participants had previously never seen before. Additionally I showed that these stimuli can elicit an N170 similar to that commonly believed to be specific to faces. 3) Configural information does affect the FIE, in that when the single-feature orientation and the second-order relations information are disrupted a FIE can still be observed by keeping the first-order relational information as close as possible to normal. I would argue that finding 2 clearly suggests that there is a strong component of expertise related to face inversion, and thus the FIE is probably not simply due to the fact that faces are "special". The effect of expertise can be explained by an associative mechanism for perceptual learning, specifically that in the MKM model. Findings 1 and 3 go to show that there are two main sources of information involved in the FIE, single feature orientation information and first-order relational information. Second order relational information does not seem to play a significant role in the FIE (though it may play a role in recognition independent of orientation). My final observation (in this thesis) on the FIE is to say that this last finding was not one that I expected when I set out to research the face inversion effect. There is something very satisfying in surprising yourself with your own research!

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